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TRANSMISSION LINE FORMULAE

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In making any calculation one may hesitate between a method which neglects quantities that may possibly need to be taken into account, and one which while dealing completely with the problem, is more laborious or intricate, and thus increases the chances of error. The advantage of the method to be described is that it permits a middle course, yielding first a rough result coinciding with that of simpler expressions, to be followed subsequently as far as may be desired, by rough approximations rapidly converging to the true result as term after term is estimated.

The result may be obtained graphically or analytically as may be preferred by the following method.

First reduce the problem, if it relates to three-phase transmission, to one of single phase.

If the connection be star, then in so far as the fundamental is concerned, the neutral points (one at each end) will be at the same potential, and may be treated as if in immediate contact. One-third of the power may then be taken as transmitted by each conductor at the voltage which exists between it and the neutral point, that is line voltage divided by $\sqrt{3}$.

The resistance and reactance are seen to be those of one conductor only, while the capacity and leakage conductance with which we have to do are estimated as the individual branches of a star connection having their common terminals on an imaginary neutral carrying no current.

In the calculation it is indifferent whether the actual arrangement be delta or star.

It is not the purpose of this paper to deal with these line constants, but a few words of caution may not be out of place. In using tables individual numbers may be in error, or a mistake may be made by using a table calculated on a different basis, perhaps with some coefficient not properly belonging, incor-

porated with it, and the special method of using such table not quoted from the original source.

Let r = resistance of one conductor.
x = reactance of one conductor.
g = leakage conductance.
b = susceptance.

If x be taken from a table, it should be, for the present purpose, one giving the reactance of one conductor at the given frequency, in accordance with

$$x = L\omega = \frac{160930}{10^9}\left(2 \log_e \frac{2D}{d} + \frac{1}{2}\right) m\,\omega \text{ henries},$$

where m is the distance of transmission in miles, by stating its value for one mile, or otherwise.

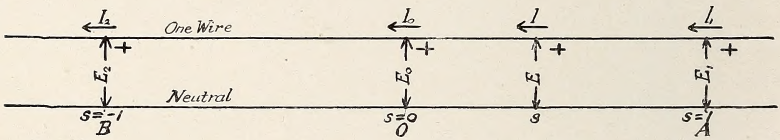
Also $b = C\omega$ should, if obtained from a table, be from one giving values agreeing with

$$C \times 10^6 = \frac{160930}{900000}\, m \div 2 \log_e \frac{2D}{d} \text{ microfarads.}$$

These preliminaries being arranged, and

$$z = r + x\,j$$
$$y = g + b\,j$$

adopted for abbreviation, take E_0 and I_0 to denote the vectors describing voltage and current respectively at one end of the



line, which for definiteness may be thought of for the present as the receiving end at O in the figure, and taken as the origin.

Take E_1 and I_1 of corresponding meaning for the other end A at $s = 1$. E and I similarly may be taken as vectors for the arbitrary point on the line whose distance from O is s.

The diagram shows the convention adopted for the signs: that is, positive instantaneous values of voltage and current are taken to be of the polarity and sense respectively indicated by the + and the arrow, and relative vector senses chosen accordingly.

Here E and I being functions of s they are given thus by Taylor's theorem:

$$E = E_0 + s\left(\frac{dE}{ds}\right)_0 + \frac{s^2}{2}\left(\frac{d^2E}{ds^2}\right)_0 + \frac{s^3}{6}\left(\frac{d^3E}{ds^3}\right)_0 +$$

or for short, D denoting differentiation once with regard to s, D^2 twice, etc.

$$E = E_0 + s(DE)_0 + \frac{s^2}{2}(D^2E)_0 + \frac{s^3}{6}(D^3E)_0 +$$

$$I = I_0 + s(DI)_0 + \frac{s^2}{2}(D^2I)_0 + \frac{s^3}{6}(D^3I)_0$$

These values may be readily determined thus: With the current as at s remaining constant at the value I the vector voltage difference for the conductor would be zI for the whole length of the line, that is for unit length as we have chosen to call it so, and consequently $\frac{dE}{ds} = zI$, or for short $DE = zI$. Similarly $DI = yE$.

$$\begin{aligned}
\text{Hence } D^2E &= D.DE = DzI = zyE \\
D^3E &= D.D^2E = DzyE = z^2yI \\
D^4E &= D.D^3E = Dz^2yI = z^2y^2E \\
D^2I &= D.DI = DyE = yzI \\
D^3I &= D.D^2I = DyzI = y^2zE \\
D^4I &= D.D^3I = Dy^2zE = y^2z^2I
\end{aligned}$$

$$\text{Therefore } E = E_0 + szI_0 + \frac{s^2}{2} zyE_0 + \frac{s^3}{6} z^2yI_0 +$$

$$\text{and } I = I_0 + syE_0 + \frac{s^2}{2} yzI_0 + \frac{s^3}{6} y^2zE_0 +$$

In particular at A the end of the line ($s = 1$)

$$E_1 = E_0 + zI_0 + \frac{1}{2} zyE_0 + \frac{1}{6} z^2yI_0 +$$

$$I_1 = I_0 + yE_0 + \frac{1}{2} yzI_0 + \frac{1}{6} y^2zE_0 +$$

By means of these two expressions the problem (so far as fundamental frequency is concerned) may be solved as accurately as the data permit, for any length of line.

As the length and voltage increase it may be necessary to take in successively additional terms; this may be carried to any extent desired.

The first term for I_1 and the first two for E_1 give the ordinary solution for short lines at low voltage. The second term for I_1 namely $yE_0 = (g + bj)\ E_0$ corrects the current for leakage and effect of capacity. The third term for E_1 corrects the drop already calculated for constant current by taking account of its variation along the line due to leakage and capacity. The third term for I_1 corrects the error made in calculating leakage and capacity effect on the basis of constant potential throughout.

At or before this point, the requirements of calculations of power transmission are likely to be satisfied, but telephonic transmission with the high frequency of some of the components of sound necessary for clear enunciation, and the long distances which are common may demand several terms more.

It is unnecessary to discuss at length the method of using this formula, as the use of complex quantities is explained in many text books.

Briefly, however, it may be stated as a caution that while the laws of algebra may be applied to the expressions given, yet if E_0 is to be taken directly as a number, I_0 (not usually

being a vector in the same direction) may not be. For example, if the current be 100 amperes at O, and be lagging so as to have a power factor of 90%, then if E_0 be represented by its value in volts as a pure number, $I_0 = 100\,p - 100\,qj$ where $p = .90$ and $p^2 + q^2 = 1$.

Thus the data may for symmetry be supposed stated in the form

$$E_0 = A_0 + B_0\,j$$
$$I_0 = M_0 + N_0\,j$$

There finally result from the above described calculation

$$E_1 = A_1 + B_1\,j$$
$$I_1 = M_1 + N_1\,j$$

As line drop is stated as the arithmetical difference in value of the line voltages it will be (when only the fundamental is considered)

$$\sqrt{3}\,\sqrt{A_1^2 + B_1^2} - \sqrt{3}\,\sqrt{A_0^2 + B_0^2}$$

The power transmitted will be $3(A_1M_1 + B_1N_1)$ watts, and that received $3(A_0M_0 + B_0N_0)$ from which the efficiency is at once found in per cent. $100\,\dfrac{A_0M_0 + B_0N_0}{A_1M_1 + B_1N_1}$

The power factor at A will be

$$(A_1M_1 + B_1N_1) \div \sqrt{A_1^2 + B_1^2}\,\sqrt{M_1^2 + N_1^2}$$

Again suppose the data given relate to the point O supplying power to the other end B of the line under given conditions represented by the same diagram as before. Then as every point on a continuous line may be considered as receiving power on one side and giving it out on the other, the point O may be so considered and the conditions at B found by inserting $s = -1$ in the formula. This will have the effect of changing from $+$ to $-$ the sign of each even numbered (odd powered) term in both the series given.

Therefore when the vectors E_0 and I_0 are given for the point O, E_2 and I_2 for the other end B of the line of the same length as before will be given by

$$E_2 = E_0 - zI_0 + \frac{1}{2}\,zyE_0 - \frac{1}{6}\,z^2yI_0 +$$

$$I_2 = I_0 - yE_0 + \frac{1}{2}\,yzI_0 - \frac{1}{6}\,y^2zE_0 +$$

These may be dealt with similarly.

THE DETERMINATION OF LATITUDE.

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In this article it is proposed to give a brief account of the principal methods of determining latitude which are adapted to the use of the surveyor's transit or the sextant, with a brief reference to the precise methods used in connection with a geodetic survey, or in the astronomical observatory.

The term *latitude* used in this connection applies to the astronomical latitude, which may be defined as the angle which the direction of the plumb line, or normal to the earth's surface, at the point of observation, makes with the plane of the equator. This line in general does not pass through the centre of the earth, the form of the earth being approximately spheroidal; and the angle which the line joining the point of observation to the earth's centre makes with the plane of the equator is termed the geocentric latitude. The latter cannot be found by observation, but its value can be computed in terms of the astronomical latitude, for a spheroid of given dimensions.

In Figure 1 PEP^1Q is a meridian section of the earth; P and P^1 the north and south poles, respectively; EQ the inter-

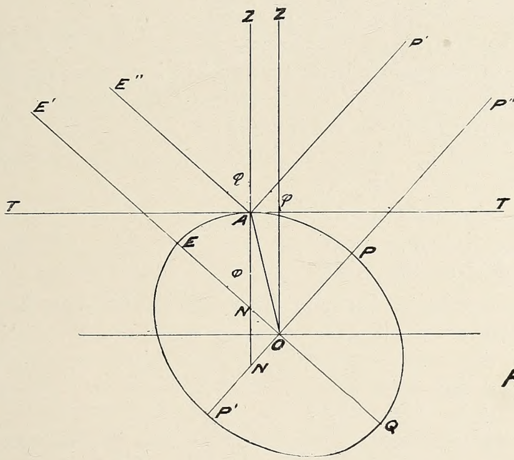

Fig. 1

section of the planes of the meridian and the equator; A any point; AT the tangent, AN the normal, and AO the radius at A. AZ is the production of AN upwards, determining the point Z the observer's zenith. AN^1E is then the astronomical latitude, and AOE the geocentric.

The maximum value of the angle OAN (the reduction of the latitude) is about 11′ 40″, occurring in latitude 45° 06′ 08″, about; and in latitude 45° the length ON or ON^1 is about nineteen miles.

If now AP'' be drawn parallel to OP'' and AE^1 to OE, then

the angle ZAE^1 is equal to the observer's latitude (astronomical), and it is evident also that this angle is equal to $P''AT^1$.

Fig. 2 is a projection of the celestial sphere on the plane of the meridian. It appears to the writer to be more convenient to consider this sphere as infinite, than as finite in extent; we may then assume the parallel lines AP'' and OP'' to intersect its surface in coincident points at P; AZ and OZ in the point Z; and AE^1 and OE^1 in E. The latitude of A, from what has been shown above, is then equal to the declination of the zenith EZ, or altitude of the elevated pole PN; so that the determination of latitude is reduced to the determination of one or the other of these arcs.

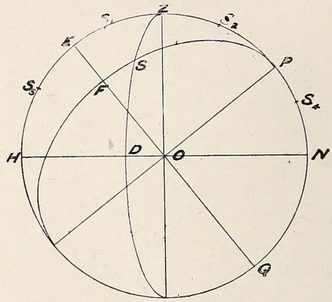

Fig. 2

Proceeding now to a discussion of the more usual methods of finding the latitude by observation we shall first describe the various methods depending upon observed altitudes or zenith distances of stars (using the term star to mean any heavenly body), taking first the method.

(1) By meridian altitudes or zenith distances.

It is assumed that the observer is provided with either a transit or a sextant, and knows how to use his instrument, so that we shall confine ourselves to a description of the mode of reduction of the observations only in each case.

If now the star be observed in either of the positions S_1, S_2, S_3 or S_4, and we denote by

δ the star's declination,

ζ its zenith distance, and

ϕ the latitude of the place

then evidently we have for the four positions, respectively

$$\phi = \delta + \zeta \quad (1)$$
$$\phi = \delta - \zeta \quad (2)$$
$$\phi = \zeta - \delta \quad (3)$$
$$\phi = 180° - \delta - \zeta \quad (4)$$

If a south declination be regarded as negative, then equation (3) is included in (1).

Again, if we denote by

p the star's polar distances, and

h its altitude

then for the positions S_2 and S_4 we may write, respectively

$$\phi = h - p \quad (5)$$
$$\phi = h + p \quad (6)$$

The star's declination is interpolated from the Nautical Almanac for the instant of observation.

Again, for two stars in the positions S_1 and S_2 we may write

$$\phi = \delta + \zeta$$
$$\phi = \delta^1 - \zeta^1$$

when by taking the mean we have

$$\phi = \frac{\delta + \delta^1}{2} + \frac{\zeta - \zeta^1}{2} \qquad (7)$$

so that it is only necessary to know the difference of the zenith distances of the two stars, not their absolute values. This quantity may be observed as follows with a surveyor's transit: The vertical axis of the instrument having been carefully plumbed, point to one of the stars S_1 or S_2 when on the meridian and read the vertical circle; then turn in azimuth through 180° and point to the other star when at the instant of transit and read again. The difference of the two vertical circle readings is the required difference of zenith distance.

For this observation the alidade of the vertical circle should be provided with an accurate level to indicate any change of inclination of that part of the instrument.

The method just described is the same in principle as Talcott's method of finding the latitude, the instrument specially designed for the purpose being the zenith telescope. This instrument is essentially an alt-azimuth in which the circles play a subordinate part, being used only for finding; while the important parts of the instrument are the filar micrometer placed in the focus of the telescope, and the sensitive latitude level attached to the alidade. In order that the micrometer may be used to measure the difference of zenith distance of the stars of a pair, they must be so selected that their zenith distances differ by less than the angular field of view of the telescope. In observing, the telescope is set at the mean zenith distance of the two stars, which are then bisected in turn by the micrometer thread of the telescope as they cross the meridian, the instrument being turned through 180° in azimuth between the observations. The difference of the micrometer readings, multiplied by the angular value of a turn of the screw, and corrected for change of inclination as indicated by the level, and for differential refraction, gives the required difference of zenith distance of the two stars. This quantity added to the mean of the declinations gives the latitude, as shown by equation (7).

The advantages of the zenith telescope as compared with the alt-azimuth in taking the above observation are apparent after a moment's consideration. In the first place, other things being equal, the precision of the former instrument should exceed that of the latter in the ratio of the focal length of the telescope of the former to the radius of the vertical circle of the latter instrument. In addition to this, however, there are the errors of a graduated circle, when its diameter exceeds twelve or fifteen inches, due to flexure, varying temperature, etc., as well as those of the graduations themselves, which completely nullify the advantage that would otherwise be gained by increasing its diameter, and thus

place still more to the credit of the zenith telescope. The errors and irregularities of a micrometer screw, on the other hand, can be readily investigated.

These advantages, together with the extreme portability of the zenith telescope, render Talcott's method the most useful one known for determining latitude in the field in connection with a geodetic survey.

(2) By an altitude out of the meridian, the time of observation being known.

This method involves a solution of the astronomical triangle ZPS (Fig. 2), the data being:

$$ZS = 90^\circ - h$$
$$PS = 90^\circ - \delta$$
$$ZPS = t \text{ (the hour angle of the star)}$$

and the required part is

$$ZP = 90^\circ - \phi$$

If the body observed is the sun, then t is the apparent time; if a star, then

$$t = \alpha - \Theta \text{ (if east of the meridian)}$$

or

$$t = \Theta - \alpha \text{ (if west of the meridian)}$$

In these equations Θ is the sidereal time of observation, and α the star's right ascension.

The fundamental relation connecting the given and the required quantities is

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t \qquad (8)$$

which is adapted for use by the introduction of the auxiliary θ as follows: Writing the equation

$$\sin h = \sin \delta \,(\sin \phi + \cos \phi \cot \delta \cos t)$$

then assuming

$$\cot \theta = \cot \delta \cos t$$

and substituting, we have

$$\sin h = \sin \delta \,(\sin \phi + \cos \phi \cot \theta)$$
$$= \frac{\sin \delta \cos (\phi - \theta)}{\sin \theta}$$

whence

$$\cos (\phi - \theta) = \frac{\sin h \sin \theta}{\sin \delta} \qquad (9)$$

θ being given by the relation

$$\tan \theta = \frac{\tan \delta}{\cos t} \qquad (10)$$

Equations (9) and (10) determine ϕ.

It is important in using any method to determine under what conditions errors in the data have the least effect upon the quantity computed from them. To investigate this we differentiate (8) and by obvious substitutions obtain

$$d\,\phi = -\cos C \sec A.\, d\,\delta + \sec A.\, d\,h + \cos \phi \tan A.\, d\,t \qquad (11)$$

in which C is the parallactic angle ZSP, and A the azimuth PZS. Regarding the errors as differentials this gives the effect of errors in the data upon the resulting latitude. It also shows that

in order that the effects of these errors should be as small as possible A must be small and C large; though with small instruments this last condition is not important, as the error in δ will then be extremely small compared with the errors of the observed quantities. All these conditions are fulfilled, however, in the case of a close circumpolar star observed at or near elongation. This suggests:

(3) The method by an altitude of the pole star.

This method only differs from that last described in the mode of reduction. On account of its small polar distance, the altitude of the star can never differ much from the latitude of the place; the method therefore consists in computing a correction to apply to the former quantity to give the latter. An expression for this correction is derived as follows:

In eq. (8), writing

$$\phi = h + x$$
$$\delta = 90° - p$$

it becomes

$$\sin h = \sin (h + x) \cos p + \cos (h + x) \sin p \cos t$$

Then expanding the sine and cosine of $h + x$, and then the sines and cosines of x and p and retaining only the first and second powers of these quantities, we have

$$\sin h = (\sin h - \frac{x^2}{2} \sin h + x \cos h) (1 - \frac{p^2}{2})$$
$$+ (\cos h - \frac{x^2}{2} \cos h - x \sin h)\ p \cos t.$$

Then multiplying out and re-arranging, we have

$$x = -p \cos t + \tfrac{1}{2} (p^2 + x^2 + 2\ p\ x \cos t) \tan h$$

Then assuming as a first approximation

$$x = -p \cos t$$

and substituting in the second term, we get

$$x = -p \cos t + \tfrac{1}{2}\ p^2 \sin^2 t \tan h$$

Therefore we have finally, p being in seconds of arc

$$\phi = h - p \cos t + \tfrac{1}{2}\ p^2 \sin 1'' \sin^2 t \tan h \qquad (12)$$

The omitted terms in this expression will never exceed 0."5.

An example is here given to illustrate the use of this expression.

The following observations were taken by the writer on June 14th, 1904, with a 3-in. transit reading to 1′:

Circle.	V. C. R.	Watch.
R.	45° 44′	14 h. 50 m. 04 s.
L.	45 43	53 46
R.	45 45	57 10
L.	45 44	59 44

The watch was regulated to sidereal time and its correction was — 20^s.

Taking the mean of the first two observations the reduction is as follows:

Mean of altitudes	=	45°	43′	30″
Refraction	=			57
h	=	45	42	33
Mean of observed times	=	14^h	51^m	55^s
Correction	=			— 20
Sid. time	=	14	51	35
Star's r. a.	=	1	24	26
t	=	13	27	09
	=	201°	47′	15″

$$\delta = 88° \; 47' \; 27''$$
$$\therefore \; p = 4353''$$

log p	=	3.638789
" cos t	=	9.967813 n
" — 4042	=	3.606602 n
" 0.5	=	1.698970
" p^2	=	7.277578
" sin 1″	=	$\bar{6}$.685575
" sin $^2 t$	=	9.139134
" tan h	=	10.010752
" 6.49	=	0.812009

h	=	45°	42′	33″
1st correction	=	1	07	22
2nd correction	=			6
ϕ	=	46	50	01

The mean of the last two observations having been reduced in the same manner, the result is

$$46° \; 50' \; 14''$$

and the mean of these two results:

$$\phi = 46° \; 50' \; 08''$$

The seconds are of course uncertain.

We shall proceed next to a description of one of the most useful methods, when small instruments are used, viz:

(4) By circum-meridian altitudes.

This term is applied to altitudes of a star when near the meridian. If a number of altitudes are observed, beginning when the star is east of the meridian and continuing until it has

reached about the same hour angle west of the meridian, the method of reduction is to compute a correction to apply to each altitude to give a value of the meridian altitude. The mean of all the values so found is then taken and the latitude deduced therefrom by one of the equations (1), (2) or (3).

To derive an expression for this reduction we again return to equation (8), writing it in the form

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \,(1 - 2 \sin^2 \tfrac{1}{2} t)$$

which becomes

$$\sin h = \cos (\phi - \delta) - \cos \phi \cos \delta .\ 2 \sin^2 \tfrac{1}{2} t$$

Then denoting by ζ_0 the meridian zenith distance we have by (1)

$$\phi - \delta = \zeta_0 = 90° - h_0$$

$$\therefore \sin h_0 - \sin h = \cos \phi \cos \delta .\ 2 \sin^2 \tfrac{1}{2} t$$

Then substituting

$$h = h_0 - x$$

in which x is the required correction to h, we have

$$\begin{aligned} \sin h &= \sin (h_0 - x) \\ &= \sin h_0 \left(1 - \frac{x^2}{2}\right) - x \cos h_0 \\ &= \sin h_0 - x \cos h_0 - \frac{x^2}{2} \sin h_0 \end{aligned}$$

$$\therefore \sin h_0 - \sin h = x \cos h_0 + \frac{x^2}{2} \sin h_0$$

and $\therefore$

$$x + \frac{x^2}{2} \tan h_0 = \frac{\cos \phi \cos \delta}{\cos h_0} 2 \sin^2 \tfrac{1}{2} t$$

Then omitting the term containing x^2 for a first approximation and substituting the value of x thus obtained in the omitted term, we obtain

$$\begin{aligned} x = &\frac{\cos \phi \cos \delta}{\cos h_0} 2 \sin^2 \tfrac{1}{2} t \\ &- \left(\frac{\cos \phi \cos \delta}{\cos h_0}\right)^2 \tan h_0\, 2 \sin^4 \tfrac{1}{2} t \end{aligned}$$

$\therefore$ in seconds of arc

$$\begin{aligned} h_0 - h = &\frac{\cos \phi \cos \delta}{\cos h_0} \cdot \frac{2 \sin^2 \frac{1}{2} t}{\sin 1''} \\ &- \left(\frac{\cos \phi \cos \delta}{\cos h_0}\right)^2 \tan h_0 \frac{2 \sin^4 \frac{1}{2} t}{\sin 1''} \qquad (13) \end{aligned}$$

A sufficiently close value of ϕ for use in the right-hand member may be found by taking the greatest observed altitude and treating it as the meridian altitude, thus finding h_0 and therefrom an approximate value of ϕ. Tables may be found in most works on practical astronomy that give the values of the terms

$$\frac{2 \sin^2 \frac{1}{2} t}{\sin 1''} \ \& \ \frac{2 \sin^4 \frac{1}{2} t}{\sin 1''}$$

for argument t. The second of these quantities amounts to 1″

for $t = 18^m$, and to $7.''5$ for $t = 30^m$, so that with small instruments this term is seldom required.

Example.—The following observations were taken by the writer with a sextant and artificial horizon on September 2nd, 1893, at a place in approximate longitude $7^h\ 50^m$ W.:

2² alt. ⊙			Watch.		
89°	59′	15″	12ʰ	32ᵐ	36ˢ
90	00	15		35	37
90	00	45		38	28
89	59	15		42	57
89	58	30		44	46
89	57	30		46	11
89	55	15		48	13

Index error $= 0''$

Watch correction $= -\ 39^m\ 08^s$

An approximate value of the latitude is found from the maximum observed altitude as follows:

Max. 2-alt.	=	90°	00′	45″
Eccentric error	=	+	2	00
	2)	90	02	45
Observed altitude	=	45	01	22
Refraction	=			58
		45	00	24
Semi-diam.	=		15	54
		45	16	18
Parallax	=			06
h_o	=	45	16	24
ζ_o	=	44	43	36
δ	=+	7	37	54
ϕ (approx.)	=	52	21	30

The computation then proceeds as follows:

App. time at noon	=	12ʰ	00ᵐ	00ˢ
Eq. of time	=			—21
Mean time	=	11	59	39
Watch correction	=		39	08
Watch time of noon	=	12	38	47

Subtracting this in turn from the observed watch times gives the corresponding hour angles.

$$
\begin{array}{lr}
\log \cos \phi & = 9.785843 \\
\log \cos \delta & = 9.996136 \\
\hline
\log \cos h_o & = 9.847403 \\
\hline
 & 19.781979 \\
 & 9.934576 \\
\hline
\end{array}
$$

Adding to this logarithm in turn those of

$$\frac{2 \sin^2 \frac{1}{2} t}{\sin 1''}$$

corresponding to the values of t found as explained above, the values of the above term being taken from a table, we obtain the logarithms of the numbers of seconds contained in the second column below. The first column contains the zenith distances of the sun found from the observed double-altitudes in the manner exemplified above.

ζ	Corr'n	ζ_o
44° 44′ 21″	1′ 05″	44° 43′ 16″
43 51	17	34
43 36	00	36
44 21	29	52
44 43	1 00	43
45 13	1 32	41
46 21	2 30	51

$$
\begin{array}{rrrr}
\text{Mean} = & 44 & 43 & 39 \\
\delta = + & 7 & 37 & 54 \\
\hline
\phi = & 52 & 21 & 33 \\
\hline
\end{array}
$$

This differs by only 3″ from the approximate value above found.

To use either of the last three methods a knowledge of the correction of the watch on local time is necessary; if this be un-

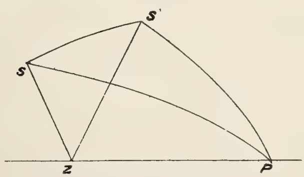

Fig 3

known, it may be determined, as well as the latitude, by the following method:

(5) By two altitudes of a star, or the altitudes of two stars, and the elapsed time between the observations.

S and S^1 (Fig. 3) are the two positions, either of the same star or of the two stars, at the instants when they are observed. It is necessary first to find the difference of their hour angles SPS^1. If the same star be observed at both observations, it is the elapsed sidereal interval between the observations; but if different stars be observed, and if

T and T^1 be the observed times, and

α and α^1 the stars' right ascensions,

then the difference of right ascension of the stars must receive a correction equal to the elapsed sidereal interval between the observations, or

$$SPS^1 = T^1 - T - (\alpha^1 - \alpha)$$

Then PS and PS^1 being known, the triangle SPS^1 may be solved, finding SS^1 and the angle PSS^1. The three sides of the triangle ZSS^1 are now known, so that it may be solved, finding the angle ZSS^1. Then $PSZ = ZSS^1 - PSS^1$. In the triangle PZS the two sides PS and ZS and their included angle are now known, so that it may be solved, finding PZ the required co-latitude. Completing the solution of the triangle ZPS we have in addition the hour angle ZPS and the azimuth PZS; so that this observation may be used to find the watch correction, and also to establish the direction of the meridian line if a transit be used.

This problem also admits of a graphical solution upon an artificial globe. Thus if the two arcs PS and PS^1 be drawn from any assumed point P on the globe, making the angle SPS^1 with one another, and if two small circles be described with S and S^1 as centres, and having angular radii equal to the zenith distances of those points found from the observations; the intersections of those circles is the position of the observer's zenith; whose angular distance from P is the co-latitude. As the circles must intersect in two points, the solution is ambiguous, but in practice an observer has always a knowledge of his latitude sufficiently close to enable him to determine which of the two values applies to his position.

There is another graphical solution of this problem which may be constructed upon a terrestrial globe, and which will serve to determine the longitude as well as the latitude, if a chronometer is used in the observations whose correction on Greenwich time, or on that of some known meridian, is given. This method is briefly as follows: If the zenith distance of a star be observed at any point on the earth's surface, the position of that point must lie on the circumference of a small circle, traced on the surface of the globe, whose angular radius is the zenith distance of the star, and whose centre is the point on the earth's surface over which the star is vertical at the instant of observation. This latter point is situated at the intersection of the meridian whose longitude is equal to the Greenwich hour angle of the star, with the parallel whose latitude is equal to the star's declination. The observations thus furnish data by which the radii and the positions of the centres of two such

"circles of position" may be found; the declinations being of course taken from the Nautical Almanac. The place of observation is then situated at one of the points of intersection of the two circles thus found. That there are two points of intersection shows that there are always two points on the earth's surface at which the same observations may be taken at the same instant of time. As the position of a point is best determined by two circles which intersect at right angles, the observer using this method will consequently choose two stars whose azimuths differ by 90°, as nearly as possible.

All the methods above described depend upon altitudes of heavenly bodies, which are affected by refraction, and which must be corrected therefor; some methods will now be given in which the observed quantity is not affected by refraction. The first to be considered is

(6) By transits of stars across the prime vertical.

Any star whose declination lies between the limits 0° and ϕ will cross the prime vertical twice in its diurnal course. In Fig. 4, S and S^1 are the two positions of a star when on the

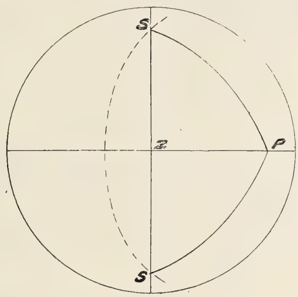

Fig. 4

prime vertical. If now the sidereal times of transit of a star be observed by means of a transit instrument adjusted in the prime vertical, the elapsed interval of time between the transits gives the angle SPS^1, and from the equality of the two triangles ZPS and ZPS^1 it follows that half the observed interval of time between the transits is equal to ZPS, the hour angle of the star when on the prime vertical. The azimuth of the star being 90° we have at once the relation

$$\tan \phi = \frac{\tan \delta}{\cos t} \qquad (14)$$

which gives the latitude.

The altitude and hour angle of a star when on the prime vertical, the latitude being known approximately, are given by the equations

$$\sin h = \frac{\sin \delta}{\sin \phi} \qquad \cos t = \frac{\tan \delta}{\tan \phi} \qquad (15)$$

and the sidereal time of transit then follows from the relation

$$\Theta = \alpha + t$$

These quantities are necessary in preparing for an observation.

This method is not much used with small instruments, but with the portable astronomical transit instrument it is one of the most accurate methods known for determining latitude. It was at one time much used for field observations, but has been superseded by Talcott's method. With the more precise instrument a considerable departure is made, in the reduction of the observations, from the simplicity of the method by equation (14), account being taken of the small deviation of the instrument in azimuth, the inclination of the rotation axis, and the collimation constant; and in some of the modifications of the method the azimuth and collimation constants are determined by the observations themselves, so that their effect upon the resulting latitude is entirely eliminated.

Another method which has recently been developed, and should prove a useful one, is

(7) By observations of stars at elongation.

When at elongation the parallactic angle of a star is a right angle, and the following relation exists between the azimuth and declination of the star and the latitude of the place.

$$\sin A = \frac{\cos \delta}{\cos \phi}$$

If now there are two stars that are at elongation within a few minutes of each other, one east and the other west of the meridian, then we have the two equations:

$$\sin A_1 = \frac{\cos \delta_1}{\cos \phi} \qquad \sin A_2 = \frac{\cos \delta_2}{\cos \phi} \tag{16}$$

whence

$$\frac{\sin A_1}{\sin A_2} = \frac{\cos \delta_1}{\cos \delta_2}$$

from which by composition and division we have

$$\frac{\sin A_1 + \sin A_2}{\sin A_1 - \sin A_2} = \frac{\cos \delta_1 + \cos \delta_2}{\cos \delta_1 - \cos \delta_2}$$

From this we find

$$\tan \tfrac{1}{2}(A_1 + A_2) =$$
$$-\cot \tfrac{1}{2}(\delta_1 + \delta_2) \cot \tfrac{1}{2}(\delta_1 - \delta_2) \tan \tfrac{1}{2}(A_1 - A_2)$$

or $\tan \tfrac{1}{2}(A_1 - A_2) =$

$$-\tan \tfrac{1}{2}(A_1 + A_2) \tan \tfrac{1}{2}(\delta_1 + \delta_2) \tan \tfrac{1}{2}(\delta_1 - \delta_2) \tag{17}$$

Now the sum of the azimuths of the two stars may be observed by pointing the telescope of a transit to the stars in turn, when at elongation, and reading the horizontal circle at each pointing; the difference of the readings is the sum of the azimuths. On finding the difference of the azimuths by equation (17), the sum and difference then give the separate azi-

muths. The latitude then follows from either of the equations:

$$\cos \phi = \frac{\cos \delta_1}{\sin A_1} = \frac{\cos \delta_2}{\sin A_2} \qquad (18)$$

It can be shown theoretically that the best stars for observation are those whose declinations exceed the latitude as little as possible, and therefore whose azimuths are large and zenith distances small when at elongation. There is a practical limit, however, beyond which this principle cannot be carried; as at small zenith distances the effect of inclination of axis or collimation error becomes very marked. The former varies as the cotang., and the latter as the cosec., of the zenith distance, and therefore the errors in these adjustments will be multiplied by those ratios, so that the total effect of instrumental errors may be very noticeable. This effect, however, may be largely eliminated by observing a second pair, or each alternate pair, of stars, with the instrument reversed.

The above method was due to Prof. J. S. Corti, of the National Engineering School, San Juan (Arg. Rep.)

A few years ago the writer adapted this method to the observation of any number of stars on a given night, observing east and west stars in any order, but preserving an approximate equality in their numbers. Each star observed furnishes an equation of the form

$$d\,\phi \tan \phi^1 \mp c \tan \delta \pm d\,R_0 \cot A^1 + \frac{1}{\sin 1''}\left(\frac{\cot \delta}{\sin A^1 \cos \phi^1} - 1\right) = O \qquad (19)$$

in which

ϕ^1 denotes an assumed approximate value of the latitude,
$d\phi$ a correction to this value, to be determined,
c the collimation constant of the instrument
$d\,R_0$ a correction to $R_0{}^1$, the assumed meridian horizontal circle reading
A^1 an approximate azimuth of the star, given by the equation

$$A^1 = (R^1 + b \tan h) - R_0{}^1$$

where

R^1 is the horizontal circle reading on pointing to the star, and
b the inclination of the horizontal axis.

Upper signs are to be used for an eastern elongation, and lower signs for a western.

The unknowns in the above equation are $d\phi$ c and $d\,R_0$. An equation is formed for each star observed—the number of stars being at least three—and the resulting equations are solved by least squares. As the collimation constant is determined by the reduction its effect is eliminated from the result.

An account of this method by the writer is given in No. 16 of the transactions of the Engineering Society.

The above methods for determining latitude are the best available when the most precise results are desired. There are,

however, some approximate methods which are sometimes useful to the explorer; as, for instance, that by observing the azimuth of a heavenly body with a compass, when rising or setting; or by observing the rate of change of zenith distance of a heavenly body when near the prime vertical. This last method deserves perhaps more than a passing notice, on account of the ease with which it can be applied. By differentiating equation (8) we have

$$\cos h \frac{d\,h}{d\,t} = -\cos\phi \cos\delta \sin t$$

or

$$\frac{d\,\zeta}{d\,t} = \frac{\cos\phi \cos\delta \sin t}{\cos h}$$

But

$$\frac{\sin t}{\cos h} = \frac{\sin A}{\cos\delta}$$

$\therefore$

$$\frac{d\,\zeta}{d\,t} = \cos\phi \sin A$$

or

$$\cos\phi = \frac{d\,\zeta}{d\,t} \operatorname{cosec} A \tag{20}$$

the required expression for the latitude.

This formula can best be applied by noting the interval of time that the sun requires to change its zenith distance by an amount equal to its angular diameter, by observing its transit across the horizontal thread of a transit, which is firmly clamped in altitude. The observation may also be taken with a sextant, by noting the times of contact of the two images of the sun, keeping the index firmly clamped during the observation. The sun's angular semi-diameter is given by the Nautical Almanac, which is half the change of zenith distance.

The advantage of the method lies in the fact that the declination of the sun does not enter into the problem; and this statement also applies to refraction, as the altitude is the same at both contacts. If the observation is made near the prime vertical the azimuth need only be known approximately.

To show, however, that caution must be observed in using these approximate methods, we shall determine the effect of a small error in the observed interval dt. Differentiating equation (20) we find

$$d\phi = \frac{d\,(dt)}{dt \tan\phi \sin 1''} \tag{21}$$

which shows in the first place that the error diminishes as the latitude increases, assuming that large and small values of dt can be observed with equal precision. Then applying the expression to an example by taking

$$d\,(dt) = 1^s \qquad dt = 217.^s6 \qquad \phi = 43^\circ\ 40'$$

we find $\quad d\phi = 16'\ 33''$

which is the error in the latitude resulting from an error of 1^s in the observed time interval. It is clear then that it is only by taking the mean of the results of a large number of observations that we can hope to obtain even an approximation to the truth.

DISCUSSION—THE YOUNG CIVIL ENGINEER

DISCUSSION BY HENRY W. HODGE

At Mr. Stern's request I join in the discussion of his article on "The Young Civil Engineer," though I do not think that I can add anything of value to his able advice to the technical graduate.

The technically educated engineer is rapidly advancing the profession of civil engineering, and we are no longer looked upon as high grade mechanics, as we were but a short time ago, but the public recognize the modern civil engineer not only as a man of high scientific training, but also as a public benefactor, as his achievements have made him a leader in advancing the development of the earth's natural resources and bringing the benefits of modern civilization within the reach of all. It should, therefore, be the aim of all young engineers to keep advancing this standing of the profession, and this can only be done by men of well rounded education and general knowledge; men who can favorably impress other men, and who can "shine" not only among their own professional associates who know their technical ability, but also among men of other walks of life who must be impressed with their ability before they will entrust great enterprises to their direction.

Therefore, I would advise every young engineer to try to add to his general knowledge, either by a classical course in college or by reading and travel, so that he will have a general knowledge of matters outside the world of science, in which we are apt to become uninteresting "experts."

While Mr. Stern's advice to change early positions occasionally so as to gather varied experience is good, I have found the young engineer rather inclined to change too often, as he finds the doing of the same thing for a length of time monotonous, and gets tired and desires a change, so that he is liable to lose that absolute confidence which comes only by doing a thing until it becomes second nature, so my advice is to learn to do at least one thing thoroughly, and if you can properly apply this special ability, you are bound to succeed. There are many brilliant engineers who are unknown because they have not the ability to impress their knowledge on men who require engineering services. You must not only be confident of your own ability to carry out great engineering undertakings, but you must be able to make the "captains of industry" and the "Napoleons of

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Henry W. Hodge, Consulting Engineer, New York City. Mr. Hodge is a graduate of Rensaeller and a member of the firm of Boller & Hodge, who are the leading bridge engineers in professional practice in the United States. They have just been recently retained as engineers for the new bridge to built over the Mississippi River at St. Louis. They were also the engineers for the Singer Tower, New York City.

finance" share your confidence, and to do this you must make clear and concise statements of engineering matters, and yet free from details and technicalities which only confuse the man of affairs, you must be able to write a short letter that clearly defines the subject matter, and you must at all times be sure that your employer is confident that you know what you are about and can rid himself of all responsibility in the assurance that he has a fully competent engineer with good technical training. With a broad general knowledge of men of the world, and a personality which impresses men with your ability, you are bound to succeed, as never was the engineering field so large or the demand for engineers who have the knowledge and the daring to attempt large enterprises so great.

DISCUSSION BY ROBERT BREWSTER STANTON.

Mr. Eugene W. Stern has requested me to discuss his paper "The Young Civil Engineer," published in the January number of "Applied Science." Mr. Stern's paper covers the field so well as to character, duties and work of a young civil engineer which should tend to make him a success in his chosen profession, that I have but one remark to make upon the paper as it is.

The qualifications required to start with, given by Mr. Stern as "endurance of mind and body, adaptability, thoroughness, efficiency, intensity and imagination for possibilities," and all the other good qualities enumerated, are magnificent traits of character, but they are not necessarily peculiar to the make up of an engineer. They are all good and serviceable, but just as applicable to any other profession, trade or occupation. The real—and hence successful—engineering requires something else to start with.

One of my assistants in the building of the Cincinnati Southern Railway, after spending several years on that work in the Cumberland Mountains of East Tennessee, gave the qualifications of a young engineer thus:—"He must be composed of one-third mule, one-third dog and one-third angel; the mule to be able to stand the labor, the dog to stand the kicks, and the angel to enable him to carry through his work in a cheerful manner." These qualities were peculiarly requisite during the earlier railroad construction in the Rocky Mountain region and beyond, where he later went. But my friend left out the one pre-requisite—a quality which he himself did not possess. He had nearly all—if not every one—of the qualities enumerated by Mr. Stern, and a technical education far superior to most suc-

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Robert B. Stanton, New York City. Mr. Stanton is a consulting and mining engineer with an international reputation. In 1889 he made a survey through the Grand Canyon of Colorado—a very daring undertaking. He has also explored in Sumatra and Java. He is a graduate of Miami University.

cessful engineers, and yet he soon quit engineering and went to farming.

This pre-requisite necessity of which I am speaking is very hard to define accurately. To begin with, the engineer—like the poet—is born, not made, and in that borning he is given a quality which I may call the engineering instinct, which can be acquired in no other way. We all recognize the fact that there is an indescribable quality, trait or something that goes to make the poet, the artist, which all the good qualities of body, mind or soul, and all the education in the world cannot produce, though they may train and improve it. Is it not so—and even to a greater degree—with the profession of engineering—whether civil, mining, mechanical, electrical or what not?

If this is so, then the first thing for a young engineer—or more properly speaking, a young man who hopes some day to become an engineer—is to find out whether he possess that inborn instinct. How, with his want of experience, is he to satisfy himself of this fact? That is not an easy question to answer, but the evidence of the fact begins with a love, a real all pervading love, of doing things for the very sake of the things accomplished; that is, a love of accomplishing such things as are included in the noted definition by Telford of the profession of civil engineering, found in the first charter of the Institution of Civil Engineers. The love will become stronger and stronger, and when it is founded on that true, inborn instinct, one can no more help being an engineer than he can help breathing and continue to exist. I spent many years with Mr. Jacob Blickensderfer, that famous railway engineer of the west, in locating and building some of the early Rocky Mountain and Pacific railways, and I said to him one day while he was Chief Engineer of the Union Pacific and nearly 70 years old, "Mr. Blickenderfer, why don't you quit such trying work and rest?" He replied, "I know it is a dog's life, but I can't quit. I love it."

This natural born love of an engineer's work should not be confused with ordinary "bent of mind;" I think it is something more. Robert Burns had a bent of mind for several things other than poetry, but it was his poet's nature and poet's love that compelled him to write those sweet songs that have touched the hearts of men and women all over the world.

The young man, then, the prospective engineer, having discovered that he posseses that inborn instinct, what is his next step? Educate it, cultivate it, in every way possible—in college, in the university, in the professional school. Is a thorough technical training in advance absolutely necessary for the success of every engineer? James B. Eads was a most noted and successful engineer—he was truly born one—yet he lacked in his preparation for his work that thorough technical training such as is now given in our great engineering schools, in fact, he never went to any school after he was thirteen. If any young

man has the time and means at his disposal he should go to the very limit in his education—the technical education of an engineer—that is, acquire the most perfect tools with which to execute his future work. If, however, this cannot be done, there is still a place, and a successful career, for a young man with a good, ordinary high school or college education even in the profession of engineering. The necessary technical knowledge can be acquired as he goes on with his work—in his room at night, or around the camp fire in the wilderness. It has been done many, many times, and can be done again, that is, provided he has been educated and trained in his preparatory studies or around the fireside at home, to think clearly, reason correctly, and has the ability to put two and two together when he sees them separately in the many conditions of nature. This may seem a trite remark, but is not the fact that a large proportion of "young engineers" coming from the great technical engineering schools have their brains full of the details of technical knowledge, abstruse deductions and mathematical formulae—usually only committed to memory—and with only a minimum amount of ability to think clearly and reason logically; and the saddest absence of the power to put together the various "twos" found in nature which at first sight seem to be separate and distinct phenomena, and yet which are in truth intimately connected, and when in many cases their union, if recognized, would be found to be the direct cause of the effect so easily and clearly visible to anyone? And again, is not the lack of this ability, as above stated, the cause of the failure of so many young men who start into the profession, to become even "young engineers"? This has been my experience with the majority of young men who have been associated with me in engineering work.

A more extended discussion of this phase of the subject will be found in Vol. 53, page 307, Trans. Am. Soc. C. E., in the writer's discussion of a paper on "Lateral Earth Pressures."

In conclusion, then, the greatest necessity for the young engineer is, in my opinion to acquire the habit of logical analysis, and systematic combinaton, of the phenomena of nature, and in doing this, of course, to exercise every one of the manly qualities so well set out in Mr. Stern's paper.

DISCUSSION BY OTTO M. EIDLITZ

I have read Mr. Stern's article, "The Young Civil Engineer," and think that he has covered the subject thoroughly. From actual experience in the conduct of my own business there are a few points that might be amplified, although he clearly indicates them in his paper. Many a graduate of a technical school

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Otto M. Eidlitz, New York City. Mr. Eidlitz is graduate of Cornell University in Civil Engineering of the class of 1881, and for many years has been at the head of the most thoroughly efficient firm of builders in that city.

is under the impression that if he has made his degree and received reasonable commendation from his instructors, the training he has imbibed at his college will be the means of immediate and permanent employment.

Although this might have been correct within limits fifteen or twenty years ago, it does not hold to-day, due to the fact that year by year the country is flooded with college graduates; so that to-day the personal equation counts as much, or more, than the work represented by the diploma.

The young engineer who enters an employment to-day must make up his mind that it is not so much his technical training which is of import, as it is his general efficiency, integrity, executive ability and above all, his desire to do as much work as a man can do.

There are few firms or corporations who will not, sooner or later, recognize the unselfish effort and devotion of the college man, provided he does not believe himself above the work allotted to him, and checks the tendency to lord it over any of his colleagues who may not have had his scholastic opportunities. When the opportunity arrives, he may reasonably expect advancement, but he must have patience to wait for it.

Many a man handicaps himself by not remaining long enough in one employment. If he is only seeking an opportunity to have his weekly salary increased, he very often sacrifices his chances for ultimate and permanent success to secure immediate pecuniary advancement. There are, of course, cases where the question of remuneration is crucial, and to that extent the individual in that condition is handicapped.

When the young engineer enters his career, whether professional or otherwise, he should be careful in the selection of his first or second employment, and then stick to it and show by his efforts that his whole aim and object in life is to give the best that is in him for the advancement of the interests of the employment with which he is associated. If he does this and has not an inflated idea of his own value, he will, within a reasonable time become of importance, and advancement will follow. He should not measure his efforts in hours, but let his employer appraise them by the results achieved. He should never forget that there are many abler men who are looking for his place and who are only prevented from securing it by the devotion and intensity of effort which the incumbent displays.

He should realize that a mistake may occur, but appreciate that most employers will condone it if it be frankly acknowledged, but that a concealment or prevarication surely spells disaster.

In short, a college training is of great value, but manhood is of vital importance and will frequently command greater respect and more immediate recognition than technical gifts.

DISCUSSION BY LOUIS L. BROWN

I have read with a great deal of interest Mr. Eugene W. Stern's article entitled "The Young Civil Engineer," appearing in the January issue of Applied Science.

There is no question about the vast importance to any young man entering the engineering profession of getting his start right. There is a great deal of practical experience, both in the office and in the shop and field, that is absolutely necessary for an engineer to have obtained in order to have a thorough grasp of his profession. This experience can only really be obtained while he is young and willing to stand for a great deal of knocking around, and to pitch in and work in very subordinate positions. I have known young engineers working as regular laborers on construction work.

No one can successfully direct and handle others until he has learnt by practical experience how it feels to be bossed.

Mr. Stern has covered the ground he attempted to in his article admirably and I might say exhaustively. Any young engineer starting out, who reads this article, and lives up to it, will certainly be heard from if he has any natural ability at all.

DISCUSSION BY T. H. ALISON

The writer has been requested to discuss the splendid paper "The Young Civil Engineer," by Mr. E. W. Stern. It certainly portrays necessary qualifications and their disposition in order to gain success by our young and old graduates in the engineering world. Many such characteristics are necessary to the success of an individual following any profession, but certain factors are especially required of a young civil engineer.

Advice has always been sought, sought of the more successful, but alas! it generally accomplishes little or nothing as it necessitates a perfect knowledge of the thought and conditions under which the seeker labors. Should a young man admire the personality, work and success of an older man, it is advisable that he draw out the latter in discussing his affairs and experiences. In this way many ideas are secured which may influence the younger man in determining what course he will follow. Frequently the young graduate has no particular inclination, in which case the sooner he secures any engineering position, the sooner he will find his natural bend.

Some are born bright and others acquire brightness by persistent plodding. All plod in the engineering profession, and

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L. L. Brown is a graduate of the School of Practical Science of the year 1895, and he is a thoroughly experienced civil engineer on construction, being associated with some of the most important erections of buildings in New York City.

whether or not one is naturally observant and inquisitive, it is essential that these two of many qualities be cultivated. Observation causes one to think, deduce and contrast. Whatever appears in the broad engineering world has been executed for a specific purpose. Whether it be well, reasonably or poorly rendered, it opens the channels of thought and from this one will deduce and contrast. Constant observation will stack a well stored mental library which cannot be taken away, and while books are indispensible, yet the truly cultivated, practical, observant, mind will far-out-act the book-worm and note-book faddist. It is well to remember that the minutest detail has its good purpose in a well designed article or structure. Observation is the best means towards improvement. As a leading graduate has said: "I never designed the same type of work twice without improving on the first, and when the second is finished I see how to improve again."

Inquisitiveness, the suppresser of pride, is not a failing in the young graduate. He is too prone to rely on the accrued theoretical knowledge gained at college. There is not a mechanic or laborer who cannot give practical reasons indispensable to the young graduate. Upon seeking advice of one of the leading engineers a graduate was told: "My boy, my only recommendation to you is to ask questions. Never turn your back on an open drain if there appears something of which you desire to be informed. Some of the best points I have gained have been from conversation with common laborers." Certainly the question of inquisitiveness can be carried too far, and a reasonable and common-sense degree only is advocated.

Mr. Stern's paper has outlined in a comprehensive and efficient manner the many characteristics of an ideal engineer. It is worthy of close attention, and as the graduates grow older, no doubt they will realize more forcibly the good sense therein contained.

No attempt has been made to criticise Mr. Stern's paper, but these two points appeal to the writer as being very essential.

Drive the nail "observation" home with the hammer "inquisitiveness."

DISCUSSION BY JAS. H. KENNEDY

Having read with considerable pleasure the admirable article of Mr. E. W. Stern in the January Applied Science, it has occurred to me that Mr. Stern has passed over too hastily the real question uppermost in the mind of the student as he is about to graduate from the college and, as the editor invites a discussion of the paper, I cannot resist the temptation to write for the benefit of a few, at least, of the students of our Alma Mater a few thoughts that it is hoped may be of use to them.

If memory serves me correctly, when I was leaving school

Jas. H. Kennedy—A graduate of the School of Practical Science, '82. He is Asst. Chief Engineer of the Vancouver, Victoria & Eastern Railway & Navigation Co.

the question was not so much "What shall I do next?" as "Shall I find anything to do?" and, judging from the number of applications for employment received every spring for several years back, not only from graduates of our Alma Mater but from many other colleges, a great many others have been face to face with the same momentous question, and it will ever be so.

To the young graduate the matter of seeking his first employment is the event of his lifetime, and a little wholesome advice at this point of his career from one who has not only been through the mill and written many applications, but has been the recipient of a fair share of the letters of not only students of our Alma Mater, but of many other colleges, may be a benefit to him. It is a fact that there are but few young graduates or undergraduates who know how to write a letter to an entire stranger asking for employment and, in making this statement, it is not insinuated that Toronto students are any greater sinners in that respect than those of other colleges and schools. The matter of writing a letter making application for employment is of considerably more importance than the average student has any idea of. Many a young fellow upon learning of a probable chance of employment, dashes off a few lines carelessly as if the whole world were waiting for him to get it done, never thinking of correcting his writing or perhaps his spelling, signs it with a flourish and addresses it to an entire stranger with the hope of receiving a favorable reply. Now, I have received many such letters and it may be interesting to some of the boys to hear what becomes of their letters. Of course they are all placed on file for future reference. Strangers are seldom employed while a worthy known young man is available. This fact of itself is generally a hardship upon the worthy student leaving college, but assuming there are no available known men when the staff is to be increased, the file of applications is taken down and letters compared. My advice to a young graduate, if he feels he should make application to a stranger for employment would be to make it his very best effort, give it his very best thought, express his meaning clearly, and in a business like way without flourishes or half written words, and sign his name in a way so there will be no mistaking it. In other words write a letter that will show up to advantage among a hundred others, or do not write at all. What chance has a man who dashes off a signature that requires the aid of the whole office staff to decipher it? Many letters are received that the contents can be easily read but the signatures are incomprehensible and they are consigned to the waste paper basket. Other things being equal the man who writes carefully and with all details accurate will be considered careful in matters of detail, and will be likely to succeed while a slipshod writer will be rejected on account of the fear of slipshod work. Nor should he resort to typewriting instead of showing up his handwriting. Many make this mistake. In order to succeed it is is not only necessary for

the application to be on file when a vacancy occurs, but there must be something in that letter to lead to the expectation that the writer is in some way superior to the writers of the other letters; and there must be no available known worthy man in sight for the vacancy. Consequently the chances of securing employment by written application at best are not at all encouraging; but sometimes do succeed. In this connection if a personal reference be excusable the writer has on many occasions, when temporarily out of employment, written, asking for employment, but not in a single instance was a situation ever obtained by a written application to an entire stranger. Possibly nobody succeeded in reading the signature; but on the other hand, in the last few years, of the several hundreds of applications received from other unfortunates, possibly not more than twenty were successful, which is but a small percentage of the total men employed; and that at a time when there seemed to be work for everybody.

To the graduate especially who wishes to take up railway work, if possible for him to do so, the writer's advice would be instead of writing letters and awaiting replies, to go personally to where work is in progress, and be on the ground when the vacancy occurs. Drop into the first opening that offers, whatever it may be, and thus he will form acquaintances among the men who are doing things, and in this way he will work upward. Strive to make up one job lead up to another, as it almost invariably does to the man who does his work well; and no man who does his work better than his fellow workers will wait very long for an opportunity to move upwards. If he does the fault will probably be in himself.

DISCUSSION OF T. KENNARD THOMSON.

It is with much pleasure that I accede to the request to discuss Mr. Stern's well written paper on what a young engineer should do.

There is a very brilliant Canadian girl in New York, the sister of an old classmate of mine and a member of a very brilliant Canadian family, who now, in one of the New York dailies, answers letters from young people seeking advice. Her counsel is always good and to the point—but she says that people do not want advice, they merely want you to agree with them. So whenever possible she tells them what she thinks they want. This reminds me of a story they tell of Roosevelt (whether it is true or not I do not know) to the effect that he on one occasion asked an old lawyer friend to make a report for him. His friend said: "Why don't you ask one of your cabinet since you have a number of the brightest lawyers in the country around you?"

T. Kennard Thomson, New York City. Mr. Thomson is a graduate of the School of Practical Science in Civil Engineering of the class of 1886. His wide experience qualifies him to make an authoritative criticism.

Roosevelt is said to have answered: "I have, but they don't agree with me on the subject."

As Mr. Stern has written on what a young man should do, I will take the liberty of writing more of my personal experience and try to give some of the advice I received as I went along and by which I tried to profit.

Before graduating in '86 I spent three summers on the Canadian Pacific Railway, starting at Medicine Hat on the South Saskatchewan River and finishing in the Selkirks. The first two seasons were spent in the bridge department under a very able engineer, Mr. W. A. Doane. Very shortly after starting, on seeing in a Toronto paper, a very inaccurately written article concerning the western country I wrote a letter to the Toronto Globe, giving my impressions and asking what they would pay for similar ones. I was delighted to get a prompt answer offering me $4 a column for all I could send them, so I sent all I could during my three summers there. About this time an old gentleman of whom I thought a great deal, said: "First, write enough to fill a book, and then boil it down to a chapter, and then if possible, condense the information to one page. In other words, cultivate brevity and simplicity. This desideratum should apply to speakers as well as to written language.

During the summer prior to graduation, I succeeded in having myself transferred from the bridge department to the field so that I obtained experience in every branch of railroad location and construction. By working every night I was able to fili two good sized note books with the designs of all the wooden bridges used on that section of the C. P. R. These notes were used as vacation work at college and have since been instrumental in securing or helping to secure several jobs in addition to netting me $75 from a periodical which published a few of them. During the first two summers my pay was $50 a month and expenses. This was raised to $75 per month and expenses for the third summer.

On finishing my work in '85 in the Selkirks I seized the opportunity to take a trip to San Francisco and back, although it made me late in getting back to college. I started by walking the "gap," 90 miles in three days, thence by rail and steamer to that beautiful "English" city of Victoria and by boat to San Francisco. I returned by the same route. As a rule, however, whenever I had to go to the same place on different occasions an effort was made to go by different routes in order to see as much of the country as possible. This enabled me to see Detroit, Chicago, Milwaukee, St. Paul, Minneapolis and Winnipeg before graduating. I had also visited the "Sault" and sailed the Great Lakes. As I was fortunate in those days in seeing a great deal of Mr. James Ross, then manager of construction, an opportunity was taken to ask him if he considered a course in a European university would be advisable after leaving the School of Practical Science. He said: "I used to work on the same road

as your Principal Galbraith. He is a good engineer and a brainy man and an engineer should not need any more university training after he turns him out. On the other hand, if you can afford to travel in Europe for perhaps a year, it will be very valuable." This I was unable to do.

About this time an old friend said: "Young man, when you get a position never worry your head about being 'fired,' but do your work in such a way that your employer will be afraid that you will get a better offer from some one else." It has often been said that we learn more from mistakes than from successes and this sage remark suggested to me the wisdom of trying to learn from the other man's mistakes instead of waiting for one's own. There is always an inclination to copy the big men, but while one can always gain much by studying such men, to try to "ape" or copy them will be ruin or dismal failure. For instance, our Duggan, who graduated three years before me and under whom I worked for two years after graduating, is one whom I would have copied if I had not convinced myself that every one has to work out his own individual path to success and follow it in his own way, taking advantage of every legitimate help or assistance that he meets on the road.

Anything that is not worth doing well is not worth doing at all and anything that is done well pays—even if it is only sweeping out an office or playing a game of football. Be accurate first, and then turn out as much work as possible. But, as Mr. Stern has intimated, don't make a calculation to six places of decimals when a hundred or even a thousand pounds or dollars would not affect the result. An illustration or two will show what I mean. An engineer once made a survey of several acres, taking an immense number of levels, every reading being to two places of decimals. After he had calculated the cubic contents required to fill this area to a certain height, having used the two places of decimals throughout, he estimated that as the ground was soft he had better add 12 inches to the depth to be filled. A military gentleman once paced the circumference of a circle and then calculated the diameter to six decimal points. Having known Duggan for some years as he was on the C. P. R. the second and third summers that I was west, I wrote him at the Dominion Bridge Company in the spring of '86 and, thanks to him, obtained the day after I was graduated a position in that concern at $40 a month. In six weeks or so after working as hard as possible and being convinced that my chief was satisfied with my work, I struck for $50 and got it, and about September of the same year got $60.

There is no work that a man can do that teaches accuracy quite as well as the making of drawings in a bridge company's office. Every engineer would be benefitted by such an experience. Every engineer should be able to handle surveying instruments and be able to make good plain drawings. Even now I occasionally go back to the drawing board myself and have

been paid $50 or more a day by former employers for making drawings for them for special purposes. This is mentioned because many young men think that they will soon be too big to make drawings themselves and do not take the trouble to become proficient.

While I was getting $60 a month at Lachine, I was offered $100 a month and expenses as resident engineer on a Western railroad, but feeling that I knew enough about that work for the time, and not enough about bridge designing, I refused it. About fifteen months after graduating I asked for $75. This the President of the company told the Chief Engineer he would not pay, as he could get all the men he wanted for $50. He was then paying me $60. I forthwith requested a permanent leave of absence which, after considerable discussion, was withdrawn on condition of a two weeks' vacation being thrown in with the $75 a month. It might be stated here that during my last year at college I had met a Toronto girl whom I made up my mind almost at first sight to marry if I could. I took this vacation to win her consent. Being so fortunate in this respect myself, my strong belief in early marriages (24 or 25) has increased.

Two years at the Dominion Bridge Company which experience included the making of blue prints, tracings, shop drawings, show drawings, bills of material, shipping bills, etc., and the spending of much time in the shop, seemed sufficient, especially as I was in a hurry to get married. I gave up my position and came to New York on "spec," and in four days struck a job in the Pencoyd Bridge Company through calling and introducing myself to Mr. C. C. Schneider, chief engineer, who then had an office in New York and who has done much for me since. I was married that fall, and decided to settle in Philadelphia for some years. The next spring, however, we thought it would be a good scheme to attend the convention of the American Society of Civil Engineers at the Paris Exposition. Not being able to obtain leave of absence it was necessary to resign my position. A glance at the salary diagram will show that nothing was lost by this, for by a curious streak of luck my old company was hard up for men when we returned. I had tried unsuccessfully to get a job in Montreal, Toronto, Detroit and New York.

We have never regretted the four months thus spent in Europe. We again settled down "for years" but in January my first chief, Mr. Doane of the Rockies, offered the position of Bridge Engineer of the Ohio Extension of the Norfolk & Western R. R. at a salary of $150 a month. The Bridge Company, which had raised the salary every time another bridge company made me an offer—one of which came from Duggan—was only too glad to have a believer of Pencoyd secure such a position, and let me go. This position gave me experience in the design and construction of 129 bridges, requiring frequent trips to the most important bridge shops in the country. It was held for one and a half years, until an offer of $200 was obtained with a consulting

engineer in New York. After about two years with him, going on the assumption that one can get almost as much for half his time as for the whole of it, I obtained the position of Chief Engineer of one of the best foundation contractors in the country with the privilege of handling all the outside work I could get. This I held for eight years, while working up a good consulting practice.

Naturally, I am grateful for the advice Dean Galbraith gave us on graduating: "Spend ten years getting as great a variety of work or experience as possible and see as much of the country as you can. It has seemed to me that it is nearly always desirable to obtain the largest salary possible on the principle that the employer is going to give the best work to the highest paid men. The most effectual way to obtain an increase in salary after one has made his value felt is to obtain a better offer from some one else. But one who threatens to leave if he does not get a raise and then stays after being refused has given himself a very black eye. Never give your employer a chance to tell you to work harder or longer. In emergencies don't count the hours. I have been 86 hours on a stretch on my feet. As a regular thing an employer is foolish to work his men more than eight hours a day, but in special cases the clock should not be considered.

If you want to get there—whenever you feel that you are losing interest in your work, get out and kick yourself before your employer gets on to you and don't get into a rut. Nothing that is easy to obtain is worth having. One of the most pitiful sights is to see a square peg in a round hole. I knew a beautiful draftsman who was absolutely wanting in the originality essential in an engineer, whose pay after a certain time kept decreasing as well as the quality of his work. He would have made a success on the stage. Another man made a failure as a clerk where he would have been a genius in another line. There was a brilliant chess player who plodded along on a drafting board where he did not belong. There are mighty few industrious, intelligent men who would not obtain great success in some line if they only had the courage to find out what it is and drop what thy are doing.

An old faithful employee, who had fallen into a rut, once went to the head of the firm with whom he had grown old, and bitterly complained that a younger man had been put over him. The employer said: "Mr. Jones see what is making that noise." Jones went to the next room and in a few minutes returned with the information that there was a big crowd in the street. See what the crowd is doing." Jones came back and said: "They are watching a lot of cattle." "See where the cattle are going." Jones came back and reported: "South." "See how many there are." Jones came back with the approximate number. The employer then asked Jones to sit down while he rang for the young man, to whom he said: "Brown, see what that noise

is about." In a few minutes Brown came back and reported: "There is a big crowd of people in the street watching 500 head of cattle which Swift & Co., have sent from Chicago to Jackson & Co. at the other end of the street." The young man retired and the employer kindly turned to his old employee and said: "You see, my friend, why the wide-awake man gets ahead."

But enough of this or your good editor will get so tired that he will throw the whole discussion into the fire. As it is, I must rely on him to blue pencil what he considers of no interest to you, or otherwise objectionable.

ALUMINIUM

J. A. McKENZIE WILLIAMS, '09

The present state of the metal market displays an unprecedented condition as regards aluminium.

This metal is now produced in such enormous quantities, compared with the production of a few years since, and the time of expiration of the American patents is drawing so close (Feb. 1909), that the different producers in operation at present are beginning the competitive struggle which has been so notable for its absence during the preceding years.

The range of quotations since Dec. 1907, has been from 42c to 13½c per pound, this latter figure being one of the late quotations in the British market. At the beginning of the year 1908 there was a notable decline in the British market from 33c to 22c, and a corresponding decline in the American market from 38c to 33c.

The American producers have always followed the railroad procedure of "charging all the traffic would bear," and in addition to this have been, and still are, protected by a tariff of 8c. per pound which effectively prevents imports of aluminium from foreign markets, and which keeps the quotations at least 8c higher than European prices.

In Britain and the Continent the various companies were until recently producing under license from patentees, and by establishing an "understanding" were able to prevent any disturbance of the market, and maintain high prices until about the 30th of Sept. of this year when this arrangement terminated, and the free competition began which has so speedily given us the satisfaction of seeing aluminium take rank with the old staples, copper, zinc, tin, etc.

Weight for weight, aluminium is now cheaper than zinc, and bulk for bulk, cheaper than copper at a market of, say, 25c.

It is probable that careful calculation will show the cost of production in America to be about 15c, and in Europe about 17½c on the average, and the present quotation of 13½c can-

not be expected to last long. However, the fact remains that aluminium has become one of the staple metals at last, and that from the present division of the price by about two, an enormously stimulated consumption may be expected. In anticipation of this, the present producers in America, Britain and elsewhere are extending their plants by doubling and trebling their present capacities.

An instance of this may be cited, the increased capacity of the various plants of the Pittsburg Reduction Co., which company was using in

	1906	1907
At Niagara, N.Y.	12,000	40,000
Massena, N.Y.	12,000	20,000
Shawenegan Falls (Que.)	5,000	15,000
Or a total horsepower of	29,000	75,000

This total capacity should give a total production of 36,000,000 lbs for the continent, of which Canada could produce about 10,000,000 lbs.

This same company has also doubled the capacity of its rolling mills at New Kensington, Penn., and is erecting one at Niagara Falls, which will have two-thirds of the capacity of the New Kensington mills. These New Kensington mills are, by the way, the only ones in America producing continuous sheets of aluminium.

In Europe there were only four companies in operation in 1907, but it is probable that there have been many additions during 1908. The total estimated capacities of these four companies in 1908, in terms of horsepower used, is

British	75,000
French	27,500
German	75,000

having a total of 177,500 H.P., and since 4 H.P. years produce 2,290 lbs. they have a possible production of about 101,400,000 lbs., working at full load.

A comparison of the production at various periods is also very interesting, and to avoid too many figures, production is given for periods about three years apart.

U. S. A. PRODUCTION

	Lbs.	Value	Per lb.
1897	4,000,000	$ 1,400,000	35c.
1900	7,150,000	2,288,000	32c.
1904	7,700,000	2,233,000	29c.
1907	26,000,000	10,000,000	42c.

WORLD PRODUCTION.

	Lbs.
1897	6,390,000
1900	14,678,000
1904	16,246,000
1907	65,058,000

So great is the present demand that it may be confidently predicted that the output will surpass 200,000,000 lbs in 5 years, and that by the end of 1908, the production will make a significant showing in comparison with copper, taking into account the relative bulks of the two metals.

On account of the present and prospective importance of aluminium, it is interesting to review briefly the past history of the development of the metallurgy of aluminium, and to glance at some of its present uses.

After a century of struggle, investigation and invention, the problem of extraction of this widely distributed element, aluminium, from some of its compounds was finally worked out to a commercial basis. Many processes were devised and suggested, some impossible, some impracticable, and some workable, but ruled out on account of their high cost. Finally from the many, two only survive the test of commercial application, that of Charles M. Hall, of the United States, and that of Paul L. Heroult, of France, and which processes are practically identical.

The various methods of producing aluminium may be classified under one of the three following heads:—

(1) CHEMICAL METHODS.

(2) ELECTRICAL METHODS (Electrical, as distinguished from Electrolytic, i.e., methods which utilize the heating effect only, and which could be carried out by other methods provided the necessary temperature could be attained).

(3) ELECTROLYTIC METHODS:—i.e., methods making use of the chemical effects of the passage of a current of electricity. For example, a common electrolytic process is the passage of a current of electricity through a solution of, say, copper sulphate, as in refining copper. The current enters the solution by a copper electrode, called the anode, passes through the solution of copper sulphate, which is decomposed thereby and is the electrolyte or bath and then out by a second electrode of copper which is called the cathode.

(1) CHEMICAL METHODS—(Running over the principal methods rapidly).

In 1827 Wohler was successful in reducing the anhydrous chloride of aluminium by means of potassium.

In 1855 St. Claire-Deville simplified the method of Wohler by using the double chloride of aluminium and sodium — Al_2Cl_64NaCl, and using the metallic sodium which was much cheaper than the metallic potassium. This process was conducted in France for the production of aluminium for 30 years, and was finally abandoned on account of the high cost of the sodium and the aluminium chloride, and the successful production by other methods.

In 1855 Rose had proposed the use of the mineral cryolite, i.e., $Al_2F_6.6NaF$, instead of the simple chloride, but this was not

followed till 1886, when Grabau, a German, devised another practical process to use the cryolite. In this interesting process, sulphate of aluminium was treated with cryolite, and the sodium fluoride of the cryolite reacted with the aluminium sulphate, and aluminium fluoride was formed. Thus the aluminium was all obtained in the form of the fluoride according to the equation:—

$$Al_2(SO_4)_3 + \underbrace{Al_2F_6.6NaF}_{\text{Cryolite.}} = 2Al_2F_6 + 3Na_2SO_4$$

The fluoride, which is insoluble in water, was separated, dried and heated to redness, and charged into a cold vessel lined with cryolite. The proper amount of sodium to exactly react with this fluoride, and in the form of a cube or cylinder, was now placed on the hot mass, and the whole immediately covered. A quiet action, but accompanied with great heat, then took place, which resulted in metallic aluminium, and the reproduction of an artificial cryolite according to the equation.

$$2Al_2F_6 + 3Na_2 = Al_2 + Al_2F_6.6NaF$$

The metal was found at the bottom of the mass, which was completely fused by the intense heat. The by-product could again be used for the production of the fresh fluoride Al_2F_6.

This process had the great advantage that it produced exceptionally pure aluminium, and of all chemical methods, it seems the only one which is at all likely to come into competition with electro-chemical methods, and depends essentially on a cheap sodium.

2. ELECTRICAL METHODS.

During the advances along purely chemical lines, experiments were also taking place in which electric current was playing a part, but it was not until the dynamo was invented in 1867 that any of these methods assumed a practical importance.

In 1862, Moncton had taken out a patent in England for a process in which he intended to pass a strong electrical current through a reduction chamber charged with alumina Al_2O_3 and granulated carbon, the reduction taking place by means of the carbon which was heated to the high temperature required, by the current. This at the time was not practicable on account of the cost of the current, and also because the aluminium produced absorbed so much of the carbon that the product was a grey, brittle, crumbling mass, scarcely fused, and containing carbides, carbon, and impurities present in the carbon used. Much aluminium was also carried off in the vapors, and some condensed in the upper layers of carbon.

It was not until 1884 that another electrical process, similar to above in principle, was applied, but now with greater success. This was the Cowles process, invented by the Cowles Bros. in an experimental plant at Cleveland, Ohio, and consisted essentially of passing an electric current through granulated material

of high resistance, i.e., low electrical conductivity. In consequence of this high resistance, it became red hot, and afforded all the heat required. The substance to be reduced was mixed with this granular material and thus absorbed the heat at the very place of its production.

It is seen that so far Cowles' scheme was identical with that of Moncton, but taking it for granted that satisfactory aluminum could not be so produced, they devoted their attention to the production of alloys, which on account of the high cost of pure aluminium at the time, were more generally used.

This is the key to their great success as it gave aluminum, in the form of its greatly used alloys, at a sixth of the former prices.

To accomplish this, Cowles used the mixture of Moncton, i.e., granulated carbon, alumina, to which he added granulated

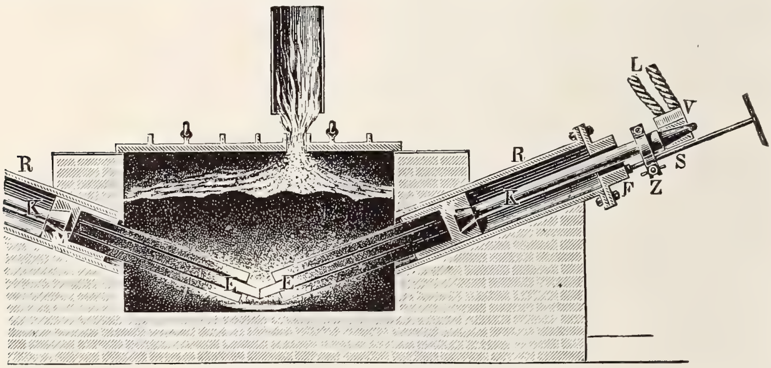

Fig. 1

copper, thus, the aluminium, as soon as produced, formed an alloy with copper, and after the run, was found as a fused mass below.

After a two hours' run, he obtained 5 lbs. of an alloy, aluminium bronze, which contained 15 to 20 per cent. of aluminium. Now by substituting this alloy, instead of copper, in the next run an alloy was obtained containing over 30 per cent aluminium. On this success, the Cowles Co. later re-organized as the Cowles Electric, Smelting & Refining Co., started their works at Lockport, N. Y., and began the production of alloys, not only of aluminium, but using the same principle they produced silicon bronze, boron bronze, and many others of practical importance. Fig. 1 illustrates the principle.

3. ELECTROLYTIC METHODS.

Now looking at the electrolytic methods, we find that in this field also there were hosts of suggestions and methods tried for the production of aluminium from aqueous solutions of various aluminium salts, but none with success. However, when

the salts alone were used and electrolyzed, the production was successful.

Among the earliest attempts, was that of Davy. He had just succeeded by his classical experiments of 1807 and 1808 in producing potassium and sodium from the fused hydroxides. He also attempted to produce aluminium by the electrolytic decomposition of Al_2O_3 alumina, but was unsuccessful. However, he achieved a measure of success when he coated a sheet of platinum, used as a positive electrode or anode, with a paste of moistened alumina, and buried in the mass the end of an iron wire as a cathode. To these two electrodes he connected a voltaic battery of 1,000 cells. On making the connection, the wire was instantly heated to a white heat, and fused at the point of contact with

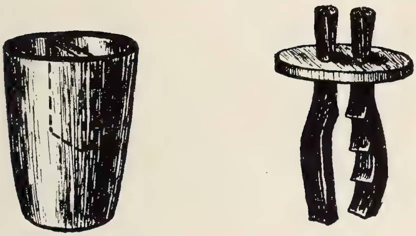

Fig. 2

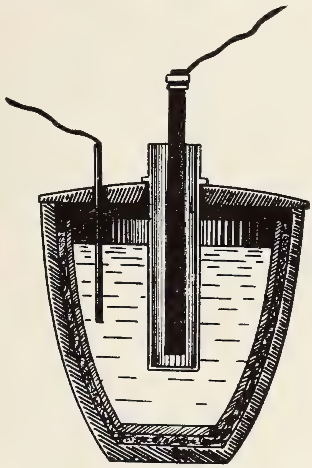

Fig. 3

the alumina paste. The metallic mass, after cooling, was both whiter and more brittle than the iron, and on dissolving in acid, a solution was obtained from which alumina could readily be separated—thus Davy had prepared the first alloy of iron and aluminium.

However, it was not until 1854 that the electrolytic production of pure aluminium was first accomplished by Prof. Bunsen, of Heidelburg, who had already produced barium, chromium and manganese. This he accomplished by the same apparatus (Fig. 2) which he had used for production of magnesium, which consists simply of a small crucible in which two small flattened and grooved carbon electrodes were dipped. The compound used was placed in the crucible and fused, the electrodes dipped in, and the current passed through—the metal produced being caught in the grooves. The apparatus was then cooled, and the solidified mass broken and the metal obtained.

St. Claire-Deville, after hearing of Bunsen's previous bril-

liant successes with chromium, manganese, barium, etc., had meanwhile been applying these methods towards the production of aluminium, and this led to the almost simultaneous discoveries by Bunsen and himself of the same method of preparation. Bunsen had, however, published his account in July, 1854, though St. Claire-Deville succeeded him by only a few weeks in August. St. Claire-Deville had modified the apparatus somewhat, (Fig. 3) and found in addition that Al_2Cl_6 could not be used as it volatilized at a low temperature, but found that the double chloride of aluminium and sodium worked well, and was fusible at a comparatively low temperature (186° C).

In carrying out the electrolysis, he gradually increased the temperature of the crucible to a point just below the melting point of aluminium, the current was passed through from the time of fusion, and continued with a gradual increase in temperature till just below the melting point of the aluminium. Now the current was stopped by taking out the electrode, the temperature raised to bright redness, and then the crucible allowed to cool. Afterwards the aluminium was found at the bottom as a regulus.

St. Claire-Deville had exhibited some of his product in 1854 at the French Academy. It was contaminated with carbon from the electrodes, which prevented the formation of a clean button. He also proposed using an anode composed of alumina and carbon, which, as the production of the aluminium proceeded at the cathode, would make up this loss by dissolving.

Interesting as these experiments of Bunsen and St. Claire-Deville were, they were not applied, on account of some practical difficulties, but they at least proved that production from fused electrolytes was possible, and so laid the foundation for the present methods.

Some of the chief difficulties were that—

(1) The carbon electrodes were disintegrated rapidly. These are now made of far greater compactness, and are therefore quite satisfactory.

(2) The fused electrolyte and metal produced, attacked the containing vessel. If a clay crucible, the clay was partially reduced, and silicon freed, and thus contaminated the metal. Porcelain crucibles have these faults, and in addition are fragile and costly. Carbon crucibles were so porous and so much attacked that they could not be used unless protected on the outside with some other substance, and metallic crucibles were unsuitable because they were attacked, and the aluminium produced formed an alloy.

(3) No suitable substance is known for making crucibles for containing the fused Halogen salts which could be heated externally.

Hosts of others in the next 25 years obtained patents on various methods, and among them Henderson in England in a

patent in 1886 approached closely to the modern methods, but was at fault in still clinging to the external heating.

The problem had awakened wide interest, and among the ranks of the investigators were found Charles M. Hall and Paul L. Heroult, then both students, both 23 years of age, now world-famed electro-metallurgists. Hall was taking a classical course at Oberlin College, Ohio, and graduated in 1885. During the course he had but one term of chemistry, which, however, so captivated him that he spent his next year in the Oberlin Laboratory with the special object of finding an electrical method of commercially producing aluminium. He used the common voltaic cells, and built up a battery, using a gasoline heater to fuse his electrolyte (Fig. 4).

His method of attack was to find a solvent for alumina which would fuse readily, and from this solution obtain aluminium by electrolysis. At first he was not successful, as his clay crucibles

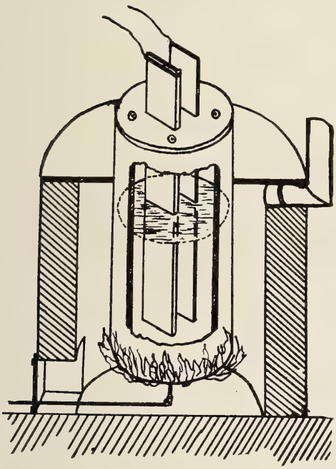

Fig. 4

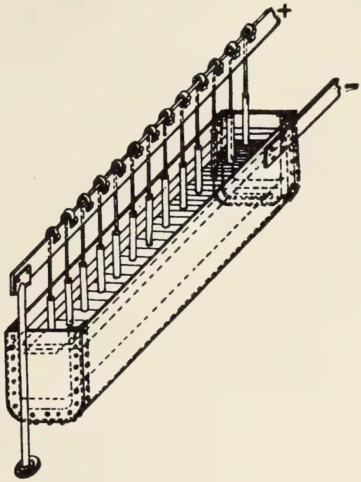

Fig. 5

were destroyed by the fused salt, and it was only when he lined his crucibles with a mixture of tar and ground retort carbon that he was successful in getting a yield of metal. The solvent he used was cryolite, and he found, as is generally the case, that the mixture melted at a lower temperature than either the alumina (Al_2O_3) or cryolite alone.

He now went to Boston, raised money to continue experiments and rented power from a small dynamo for four months, and experimented with copper electrodes which, however, were unsatisfactory, and he finally concluded that by improving the carbon electrodes, they would be the most satisfactory of all electrodes, for commercial work.

In July, 1886, he applied for his first patent, the basic principle of which was using as a solvent the double fluoride of aluminium, and some more electropositive metal, in this case ($Al_2F_6.6NaF$) cryolite.

He now returned to Oberlin determined to devise a commercial method, and being without funds, had to content himself with making bichromate cells, and working with a small iron crucible, but the results so encouraged him that in December, 1886, he went to relatives in Cleveland in order to negotiate for funds.

Meanwhile Heroult had patented in France at almost the identical date, the same process, and now had applied for a patent in the United States, and, as Hall had not as yet produced aluminium commercially, the United States Patent Office declared an interference between Hall's and Heroult's application.

He was then forced to make an agreement with Cowles Electric Smelting & Aluminium Company, by which they took an option on the process in exchange for supplying power, and giving Hall an interest if successful.

At the expiration of the time, the Cowles Co. did not take up the option, so Hall, who had now some connection, formed the Pittsburg Reduction Co. in 1888. Meanwhile the interference at the Patent Office had been decided in Hall's favor.

Now, with sufficient funds, Hall went to work on a larger scale, and by so doing was successful. In 1891 the plant was moved to New Kensington, Penn., and in 1893 the Niagara Power Co., which was just starting and looking for consumers for their power, made the Reduction Company an attractive offer at $18 per H.P. a year. This they accepted, and started what is known as the "upper works," and being eminently successful, they added the "lower works" in 1896.

From this time the company has been continuously successful, and constantly increasing their capacity. They found that by increasing the size of the vessel, or cell, that the heat generated by the reaction maintained the temperature sufficiently to keep the bath in a state of fusion, and so they were saved the expense of external heating (Fig. 5).

They also soon found it necessary to purify the bauxite which they used as the source of alumina. This was accomplished by mixing it with enough carbon to reduce all the impurities such as silica, iron oxide and titanium oxide, to the metallic state, and then melting in an electric furnace. The reduced impurities formed an alloy, leaving the alumina above almost chemically pure. This alumina is granular, dissolves easily, and produces a metal of high purity.

Heroult, in 1900, described how he stumbled across his process. He was attempting to electrolyze cryolite $Al_2Fl_6.6NaF$ with an iron cathode and carbon anode, and had added some double chloride Al_2Cl_64NaCl, to make the mixture melt more easily. He obtained some aluminium alloy at the iron cathode,

but observed no evolution of chlorine or fluorine at the anode, which was attacked, however, and yielded CO and CO_2. He therefore concluded that some oxide was present as an impurity. Following up this clue, he then added pure alumina Al_2O_3, and obtained only CO_2 and aluminium.

He immediately obtained a patent, and went to a manufacturer who was producing aluminium by the sodium process. This manufacturer advised him to turn his attention to alloys as the use of the pure metal was limited. This he did, but, after working a couple of years, he learned that Hall was now making pure aluminium successfully. He therefore started production, and placed some of his product on the market about a year after Hall had started commercial production, but it was not until 1890 that he was selling a grade equal to Hall's. Heroult also patented his process in England and on the continent, and production of aluminium was carried on by four companies using his patent under license. These patents nominally expired in 1901 but extension of time was applied for and it was not till 1907 that many outside plants were contemplated in Europe. In America it was not all smooth sailing with the Pittsburg Reduction Co. This company entered suit against the Cowles Co. in 1893, and obtained an injunction restraining the Cowles Co. from the manufacture of aluminium.

Meanwhile Charles S. Bradley a very noted electrial engineer, had patented the idea of internal heating. This patent was fought by the Cowles Co., who had, since the beginning, used internal heating in their production of aluminium alloys. The Cowles Co. won their suit, and now in turn, they fought the Pittsburg Reduction Co., which Company, as was mentioned before, had abandoned their external heating, when they found that the heat evolved by the reaction was sufficient to keep the bath fused. This suit they also won, and the Pittsburg Reduction Co. was compelled to pay heavy damages. As a result of these decisions, the process was tied up, the Cowles Electric Smelting & Refining Co. owning the internal heating part of the process, and the Pittsburg Reduction Co. the electrolysis of alumina in a bath of fused cryolite. Hence neither could work without the other, and, of course, this resulted in a practical amalgamation of interests, till February, 1909, when the Bradley patent expired and the whole process became public property.

The various uses to which aluminium is put, depend for the most part, upon its low Sp. G. 2.6, its relatively high conductivity, its white color, and to the fact that the oxide which forms in air is white, and forms a compact, coherent coating over the metal which is extremely thin, resistant to further oxidation, and therefore does not detract from the appearance of the metal.

Since the Sp. G. of aluminium is 2.6 and that of copper about 8.9, therefore a given weight of aluminium will occupy about four times as great a volume as the same weight of copper; therefore, if we represent a given weight of copper by a solid

figure, then the volume of aluminium, being four times as great, would be represented by four similar figures having the same depth. Therefore, the upper surface of the aluminium would be four times that of the copper, of the same weight and depth, and now, since the conductivity of copper compared with that of aluminium, is as 1 to .6, and if we call the conductivity of the copper 1, then the conductivity of aluminum will be four times .6 = 2.4, or say, about twice that of the copper. These two considerations show that with aluminium at the same price as copper, for castings and all work where volume alone is concerned, aluminium would cost one-quarter as much as the same volume of copper, and where conductivity is concerned, since half the weight will give more than equal the conductivity, therefore, the cost would be about half that of copper.

Conductors of aluminium are now in extensive use in electrolytic works, and in electric furnace work where heavy currents at low voltage are required, some of these conductors being of great size, as for example, 2″x4″, 4″x4″, 2″x6″, and look like squared lumber. This use as conductors is not confined to large sizes. Power companies are using aluminium wires and cables, one, at least in Canada, being 90 miles in length. In the Western States aluminium wire is now greatly used, and iron wire coated with aluminium is used in place of the former galvanized products in telephone and telegraph work.

Soldering of aluminium has occasioned much difficulty on account of the film of oxide which rapidly forms on the surface, and prevents ordinary solders wetting the surface. No flux has yet been found which will dissolve this oxide and keep the metallic surface fresh long enough for ordinary soldering. To overcome this, numerous ways have been suggested, and each number of the various technical journals seems to add about as many more. Some claim to solder satisfactorily by using the untinned copper in such a way that it mechanically scratches the surface, i.e., by passing it backwards and forwards, and holding the solder against the copper while this is going on, thus the aluminium is mechanically cleared.

The Autogenous method is however probably the best, as no other metal takes part in the operation, a flux such as an alkali chloride being used, and the two surfaces to be united, pressed firmly together, and heated to a point just above the melting point of aluminium. The mechanical properties of such joints are good, and under the microscope present the same structure as aluminium itself. Sheets of aluminium 15mm. in thickness, and welded in this way have withstood 17 atmospheres. The process is useful, not only for welding wires and cables, but for aluminium apparatus, tubes, pipes, chemical apparatus, vessels, automobiles, etc. Pure aluminium is durable in sea water, but joints soldered with any other metal are attacked very readily.

Aluminium is now greatly employed as a pattern metal, it being light, easily finished with sandpaper and file.

The Wetherill zinc oxide furnace grate is cast in sand, moulded by an aluminium form. When wood was used, a great many small pieces were necessary, and with the aluminium it is all one piece, hence lessening the time and cost considerably.

Many aluminium objects are now prepared by a method similar to lead pipe, i.e., the metal is heated to a point just below melting, and squeezed out of forms continuously. In this way sheet aluminium of all gauges for automobile bodies, signs, cooking utensils, kodaks, etc., is produced. Some of the New York subway cars are lined with sheet aluminium, and the Japanese army was supplied with aluminium cooking utensils in the late war.

Aluminium pipe is also so produced, and is used for all sorts of purposes,—acetic acid plants, nitric acid condensors, in pulp mills, the finest pipe being used as needle indicators on various instruments, as in galvanometers, etc.

Rods of all sorts and shapes, from the enormous bus-bars to the finest thread-like wire for lace fabrics, mouldings of all patterns, and for various purposes are produced in this way.

Aluminium is now extensively used as a deoxidizer to produce sound castings, and many thousands of pounds are used annually for this purpose.

For plating on aluminium, no really satisfactory method yet exists by which one metal may be directly plated on aluminium; this is due to the ever present film of oxide, but it is said that by dipping first in a solution of stannous chloride and ammonium alum, a film of metallic tin coats the aluminium on which a deposit of other metals may then be satisfactorily plated.

ALLOYS

Among the chief alloys are aluminium bronze, consisting of aluminium and copper. These bronzes are greatly used in machine designs where lightness and strength must be combined, as in automobiles. They are also used for decorative work where a non-tarnishing yellow color is required. A new bronze, consisting of copper 39, iron 34, nickel 18, aluminium 9, is as hard as nickel-steel, is strong, very resistant to sea water, moist air, and acid water. Six parts added to 24 of yellow brass is said to make the brass equal in strength to the best bronze.

Aluminium and zinc alloys are also used in automobile works, alloys containing copper, aluminium, tin, and antimony for horse-shoeing, and many other alloys for special purposes are employed.

Respecting the tensile strength of some of these alloys, it is interesting to compare the tensile strength of some common products with aluminium bronze.

TENSILE STRENGTH

(Pounds per square inch)

Cast copper	24,000
Cast gun bronze	39,000
Steel plate rolled	81,000
Aluminium bronze castings	100,000
Aluminium bronze (with silicon)	130,000

Another important application of aluminium is in what are termed by the inventor, Dr. Goldschmidt, the aluminothermic reactions. When the oxides of such metals as titanium, iron, chromium, nickel, etc., are mixed with aluminium in a fine powder and some hot body applied, as a red hot iron rod, a vigorous reaction takes place by which the aluminium reduces the metallic oxide and leaves the metal in the free state. The aluminium is itself oxidized to the form of Al_2O_3, and floats on top as a slag.

This principle has been of great importance for the preparation of pure metals free from carbon. A mixture of iron oxide, Fe_2O_3, and aluminium powder is now on the market as Thermit, and finds extensive application in rail-welding and repairing broken castings of all kinds. The Russian army was supplied with Thermit for repairing their heavy ordnance, etc., during the war.

The application is a very simple matter, the greatest time being consumed in preparing the mould around the object to be repaired or welded. A conical shaped crucible is filled with Thermit mixture, a little barium peroxide added to the top, and in this a short piece of magnesium wire is placed. The crucible has an opening at the bottom, which is placed directly over the mould, and which may be opened or closed at the will of the operator. When everything is ready, the magnesium wire is lighted, and the heat soon liberates oxygen from the barium peroxide, which, uniting with the aluminium, starts the rest of the mixture reacting by the heat communicated. After a moment the vent is opened, and the molten metal allowed to flow into the mould. The heat of the reaction is so excessive that the metal it comes in contact with is soon heated to such an extent that a perfect union results.

There are still a great many other applications of aluminium which time prevents mentioning, while the near future is bound to see a great extension in the practical and every-day uses of aluminium.

N.B.—Read at a special meeting of the Chemical and Mining Section held on December 16th, 1908.

WATER METERS.

J. J. TRAILL, B.A.Sc.

Water meters may be defined as instruments by which the quantity of water flowing in a pipe is measured and the amount passed is recorded automatically. The number of meters devised is legion, if one may draw definite conclusions from patent office records, the British patent office records showing that for one period of ten years there were granted 389 patents of water meters or parts thereof. No perfect meter has been devised as yet, but this is not otherwise than should be expected, for the variety of service to which they are put is so great that most meters are designed to serve well in a few classes of work, while they may be entirely useless in other classes.

The important desiderata of a perfect meter are as follows: It should accurately measure all flows, whether fine or full; should work at very slight pressure; should work at high pressure without shock or water-hammer; should be small in bulk and easy to set and repair; should not be liable to "stick up" or stop, and when not registering when water is being passed through it should give some outward indication of the fact; and, finally, should be incapable of passing water backwards.

Meters are of two kinds, viz.: Positive and Inferential. Each of these classes may be subdivided. Positive meters measure the actual volume of the water by the action of a piston working in a cylinder which is successively emptied and filled at the completion of each stroke. The cylinder being of known dimensions affords a measure of the quantity of water discharged in a given interval of time. Inferential meters measure the velocity of the flowing water, generally by recording the revolutions of a turbine or other water wheel or, in the case of the Venturi meter, the pressure on a gauge.

Nearly all positive meters are included in the following four classes: Single cylinder reciprocating piston meters, double cylinder reciprocating piston meters, rotary piston meters (including the disc meters) and diaphragm meters.

The Kennedy meter shown in figures 1 and 2 is of the single cylinder reciprocating piston type. This meter will register the flow accurately even when so small a quantity as a drop at a time is being discharged. It is very bulky considering the quantity it will discharge, and is not, therefore, used to any extent as a domestic service meter. Its accuracy is such as to recommend it as a test meter and it is often used for this purpose, the meter to be tested being put in series with it, water run through and simultaneous readings taken on the two dials. The meter consists essentially of a cylinder and piston, a two-way cock, a tumbling weight to operate the cock and a dial on which the discharge is registered. Fig. 1. shows a section of the inlet and outlet pipes and the cock; Fig. 2, a side section of cylinder

and piston inlet and outlet pipes and cock. The packing of the piston consists of a ring of very pure soft rubber, shown between the piston and walls of the cylinder. As the piston rises water

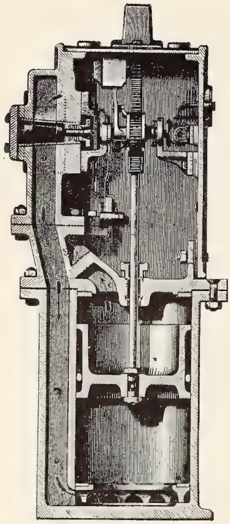

Fig. 1

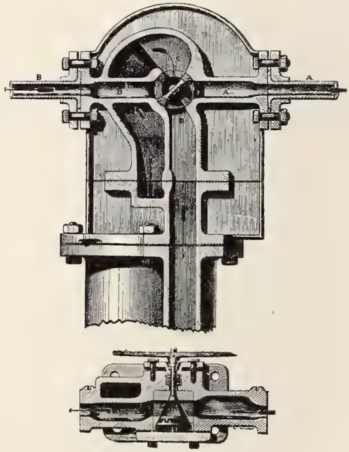

Fig. 2

flows into the bottom of the cylinder, filling it; the rack on the piston rod raises the weight by means of the pinion to which the latter is attached, until, when the end of the stroke is reached,

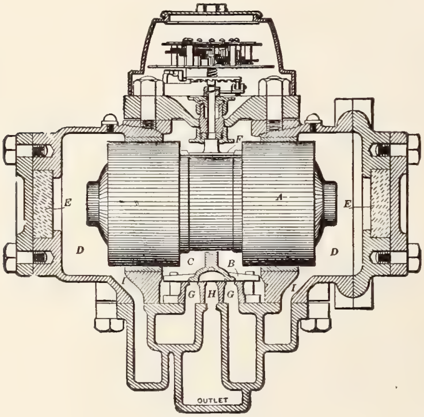

Fig. 3.

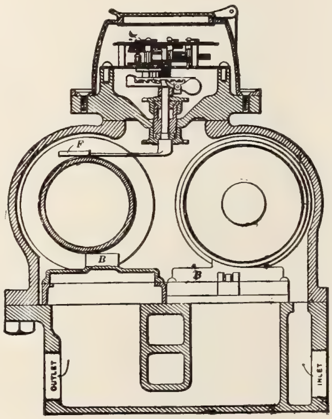

Fig 4.

the rack passes beyond the pinion, the weight falls, reversing the cock and the piston commences the return stroke. Any error which might occur through short stroking is made inef-

fective by having the counting gear record the distance travelled by the piston. With this meter there is danger of water-hammer if the piston speed becomes high.

Much more compact instruments are the double cylinder reciprocating piston meters. In these one piston actuates the valves of the other cylinder. The cylinders may be the same or different in size. Figures 3 and 4 show sections of a Worthington double cylinder meter in which both pistons are of the same size. Water flows into the cylinder under pressure from the main, displacing the piston, which, in turn, displaces the water in the other end of the cylinder, this flowing through the outlet port of the valve to the services pipes. Thus the plunger in moving displaces a fixed volume of water, discharging it

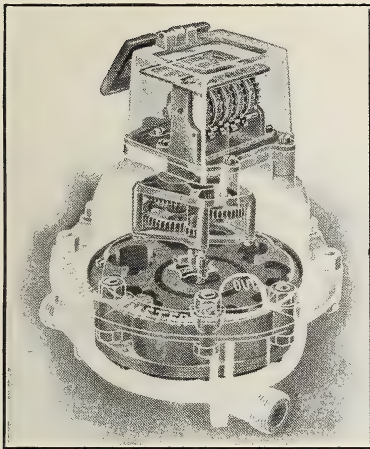

Fig. 5

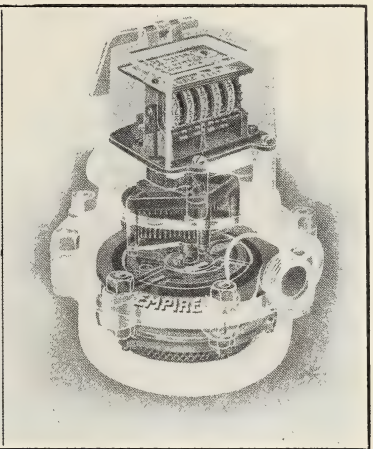

Fig. 6

through the outlet. The arrangement is such that the stroke of the two plungers alternates, the valve actuated by one admitting water behind the other. The plungers come to rest when they reach the rubber buffers at the ends of the cylinders. One plunger imparts a reciprocating motion to the lever F, which operates the counter movement through a spindle and ratchet gear. With this meter, which is otherwise a very accurate and reliable instrument, there is a danger of over-registration at fine flows through a tendency to short stroke.

Rotary piston and disc meters, engravings of which are shown in Figures 5, 6 and 7, are the next in the scale of accuracy where considerable variation in the flow is to be expected. These meters are easily kept in order, there being no valves, and, with the exception of the counting gear and piston or disc, no moving parts. The piston or disc in these meters is usually made of hard vulcanite with a specific gravity, nearly unity, the advan-

tage being a slight reduction in friction. The pistons are of various shapes, generally complicated, but the action of all meters of either class—rotary piston or disc—is essentially the same for the class.

In the rotary piston meters the action is as follows: The centre of the piston has a circular motion, the lobes working in the small chambers of the cylinder, and these alternately cover and uncover the inlet and outlet ports of each chamber. The amount of water passed per revolution is equal to the difference in volume of the cylinder and piston. In these meters provision is made for a small amount of water to pass when, through accident, the piston becomes "stuck up." This is necessary in domestic supply meters, as the meter should not cut off the

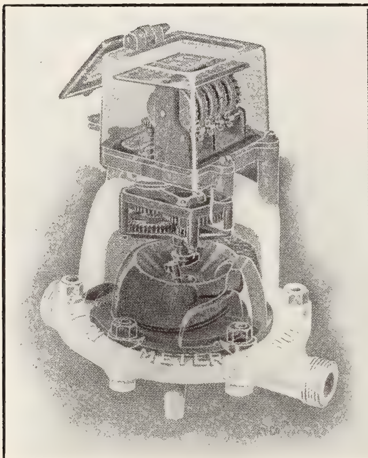

Fig. 7

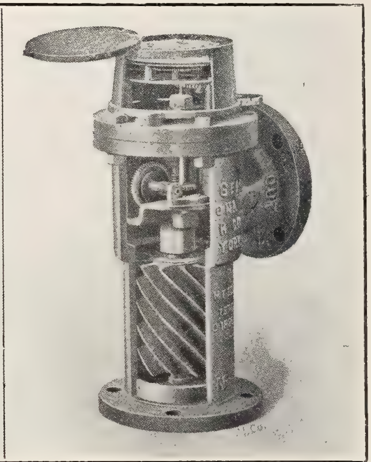

Fig. 8

supply completely, but if not registering should give some decided indication of the fact.

The meter illustrated in Figure 6 is, as it were, a transition from the rotary piston to the disc type. There is, as in the rotary piston meter, a piston, but the arrangement of inlet and outlet ports is exactly similar to that of the disc meter.

In the disc meter shown in Figure 7, a disc with the shape of a flat cone "wabbles" back and forward in such a way that one element of the cone is always in contact with the chamber in which the disc works, thus shutting off free flow from the inlet to the outlet ports. The volume of water passed per revolution is, of course, fixed by the size of the chamber.

Rotary piston and disc meters are in use to a very large extent in America for metering domestic supply. In one instance a city in one of the northern states placed an order for 15,000 disc meters at one time. Both classes are fairly accurate

over quite a wide range of flow. The life of the rotary piston meter is longer than the life of the disc meter. It is possible also by a simple repair to take up the wear of the piston for the former, but when the disc and disc chamber of the disc meter become worn the meter's usefulness is ended.

Diaphragm meters are not used to any great extent for water measurement. The meter consists of a pulsating diaphragm, in a vessel of known capacity, which is moved as the side chambers are alternately filled and emptied. The common dry gas meter is essentially a diaphragm meter.

Coming to the second general class, Inferential meters, we have first of all rotary turbine meters, a good type of this meter is shown in Fig. 8. By a comparison of the supply pipe of this meter with that of any of the positive meters it is immediately evident what a great saving in size—and hence in cost—is obtained by using a meter of this kind. The saving is at the expense of accuracy of registration at fine flow, meters of that

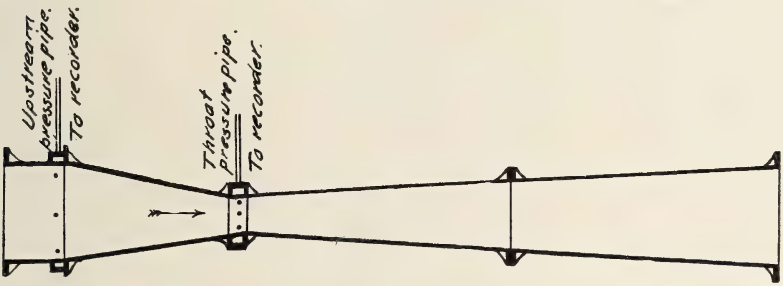

Fig. 9. Longitudinal section of Venturi Meter

kind being accurate only for medium or full flows. The action of the meter is evident from the figure.

Rotary fan meters are similar in principle to the ordinary windmill.

The Venturi meter might also be classed as an inferential meter. Briefly, the method of measurement of water by this meter is based on the fact, that when water flows through a pipe of which the section is gradually contracted and subsequently gradually increased, the pressure in the smallest section is much less than in the largest section on either side of the contraction. The discharge through the meter varies directly as the square root of the drop in pressure from the largest section upstream to the throat. For use in pumping stations the meter is furnished with an autographic recorder, which shows, by a diagram, the volume of flow. A diagram of the meter is shown in Fig. 9.

A very decided advantage of the Venturi meter is that the loss due to friction is small. The meter is very accurate, for large discharges, more accurate than any other meter.

For domestic supply the favorite meter in America is one of the positive types, usually the rotary piston or disc meter. The double cylinder reciprocating piston meter is also used frequently. European practice seems to favor the use of inferential meters for this purpose. The explanation is probably found in the different number of persons per service in America and in Europe. In America the number of people using one service is probably about ten on the average. In some cities it is as low as five. In Europe the number is much larger. In Berlin, for instance, the latest figures available state that there are 70 people per service. With this condition the flow would be fairly continuous and a cheap compact meter which will give a reasonably correct measurement is therefore used. The average number of people per service is large in nearly all European cities.

For trade supply inferential meters are almost universally used. It should be noted that inferential meters may pass large quantities of water without registering, as, if they become "stuck up" they offer very little resistance to the flow.

For measurements of municipal supply the Venturi meter is used. The Pitometer, a rated pitot tube arranged to give a photographic record of flow, is coming into use for this purpose also.

PRACTICAL METHODS OF CONCRETE CONSTRUCTION*

C. G. CLINE, '09.

This paper is not intended as a discussion of the theory of concrete, either plain or reinforced; it is intended simply to bring out some methods of concrete construction met with by the writer in a somewhat limited experience with this important material of construction.

One of the simplest uses of cement is the making of mortar for brick or stone work. It is often used where mortar made from ordinary lime would not be strong enough; or a small quantity may be mixed with lime mortar to increase its strength. When the masonry is to be exposed to moisture, cement must be used instead of lime, as lime will not set unless thorougly dry, and will gradually dissolve in water.

Cement in the form of concrete is now very commonly used for all kinds of walls, for buildings, retaining walls, dams, etc., and for foundations for buildings and machinery. Wooden forms are built up, the concrete is mixed by hand, or by machine, and placed in them. The concrete takes up the shape of the forms and hardens, so that when they are removed the wall remains.

The forms are almost universally made of lumber. The use

* Read before Civil and Architectural Section of Engineering Society, December, 1908.

of steel, either for the entire forms or for facings, has not been found satisfactory. The steel plates are easily bent and it is too expensive to be continually straightening them out. A common practice is to use 2″ lumber for lagging and 2″x6″ for studs. If 1″ lumber is used, the studs will need to be much closer and the bracing of the forms very carefully attended to. Even then the results may not be satisfactory; the whole wall may get out of alignment, or some of the boards may spring out of place and leave a rough, uneven surface on the wall.

For rough work, undressed lumber is commonly employed. On one structure, undressed lumber was used for the foundation and inside work where it would not be exposed to view. For finer work, lumber was employed which was dressed on one face and both edges; the edges must be dressed and straightened so that the planks will fit together tightly in the forms and not leave holes for the concrete to run through, making great ridges on the wall. On still more particular work, there was used matched lumber, 2″x8″ or 2″x10″. The tongues and grooves made the form much more solid and easier to keep in position and gave an even face on the finished wall.

When an especially smooth face is desired, it is a good plan to paint the inside of the forms with a coating of soap dissolved in hot water. This allows the forms to come off clean, without damaging either the lumber or the concrete. It is surprising how tightly a piece of wood will stick to the concrete wall, even when it is merely in contact with it; while if it is partly imbedded in the concrete, it is next to impossible to remove it when once the concrete has set. In foundations for machinery, it is necessary to leave a space around each anchor bolt so that it will have some play when the casting is being placed in position. This is usually done by placing a long, narrow box around each bolt before the concrete is put in the forms. These boxes should be tapered and must be removed before the concrete is entirely set or it will be impossible to withdraw them. After the machine is properly lined in, cement grout is poured into the holes, and when it hardens the machine is held firmly in position.

If it is desired to nail any wood-work to a cement surface, a piece of scantling placed against the inside of the form will become imbedded in the concrete when the form is filled and will make a solid nailing strip to which the wood-work can be fastened.

The form for a concrete wall consists of two walls of lumber. The smooth side of the lumber, if it is dressed, is, of course, placed to the inside. The studs, usually 2″x6″, are placed on the outside. The concrete, as generally used, is rather wet and soft, and when placed in the form it exerts considerable pressure in every direction. Concrete is more than twice as heavy as water, and so, although it is not as fluid, it will exert almost as great a pressure as would water. This pressure tends to move the two walls of the form apart and must be provided for in some way.

Where the wall starts from the ground and is only five or six feet high, the two sides may be held in position by braces slanting from the ground. But in very many cases this method cannot be used, and it becomes necessary to tie the two walls together. One very effective method is to use bolts which can be tightened up by nuts, wooden spreaders being used between the walls to keep the form the proper width until the concrete is placed in. In narrow walls the bolts can be driven out after the forms are removed and used again; the holes left in the wall are plastered up. But in many cases the bolts would have to be left in the wall and the ends simply cut off. The rods serve no useful purpose in the wall and their cost is considerable. A plan, which is considerably cheaper and almost as effective is to tie the walls together with strands of wire twisted until a sufficient tension is obtained to resist the pressure of the concrete. As in the last case, spreaders are used to keep the walls properly spaced. They are always removed just before the concrete comes up to them.

To avoid excessive pressure on the forms, and for other reasons, concrete is laid in layers, often not more than two feet. To make a solid wall, it is essential that these separate layers adhere to one another strongly. For this reason, when a fresh layer is being placed, the bottom layer should be perfectly clean and should be wet. The concrete is usually swept as clean as possible, and then washed with water. To make a really good joint, it is a good plan to sprinkle a little neat cement over the bottom. Sometimes the first two or three inches of the fresh layer is mixed with a little less stone in it, to ensure plenty of fine stuff at the joint. When leaving work for the day, it is a good practice to imbed plenty of big, sharp stones in the concrete, leaving half of each stone sticking up to give a good bond for the next layer. In narrow walls, where stones could not be used, short pieces of bars of iron or steel scrap or old pipe will serve the same purpose.

In starting a wall on smooth rocks, especially if the rock be sloping, great care must be taken to make sure that the wall will not slip. The rock surface should be thoroughly cleaned and washed and holes drilled at intervals and fox bolts driven in.

For ordinary work, concrete is usually mixed with a considerable amount of water, so as to make it quite soft. Then, when it is placed in the forms, it will, with the aid of a little tamping, work into all the corners and make a smooth face and a good bond. One defect of this method of mixing is that when the water evaporates it leaves the concrete more porous and diminishes the strength to some extent.

For some work, the concrete is mixed rather dry, almost like moulding sand. If properly tamped, this will be less porous and rather stronger than the other mixture; but it requires a great deal more care in handling it to be sure every corner is

filled up and no holes left. If it is not carefully tamped its strength will be greatly impaired. It is not so well adapted for ordinary walls and foundations, but is used where it has to be trowelled, such as for the top coating of floors and sidewalks.

In concrete work it is customary to mix the cement, sand, gravel and stones up to, say, two inches diameter, together in the mixer or on the board. But in most cases it is desired to use stones larger than two inches. These larger stones are taken to the forms by themselves, thoroughly washed and soaked in water, and placed in the form one by one. In a three-foot wall, rocks as big as two feet across may be used if carefully placed; and even in an eight-inch wall, four-inch rocks are all right. In one instance, old bricks were laid in an eight-inch wall with the four-inch side horizontal. Of course, the extensive use of fillers is not permissible on all works; they diminish the strength of the work to some extent and its fire-proof qualities.

In using fillers, care must be taken to keep them back a sufficient distance from the face of the wall. If a flat surface of a rock or brick comes within an inch or two of the face, the thin layer of concrete on it is apt to come off with the forms or be knocked off in some way and leave an ugly hole in the wall, exposing the filler. The same is true, to a lesser extent, of the smaller stones. But these cannot be placed by hand. So it is necessary in every wall to have a man run a spade or other tool up and down against the face of the form in such a way as to work the stones back and to give the fine part of the mixture a chance to make a smooth, even finish.

In most works it is impossible to carry up the whole structure at once. So it becomes necessary to make some provision for joining the different sections together. One method of doing this is put steel rods in the first section, leaving half the length of the rod projecting at the joint. The ends of the rods are usually bent to increase their efficiency. Another method is to nail on the inside of the form several blocks of wood slightly bevelled so that they may be removed readily. This leaves a recess into which the concrete in the other section will run.

In attempting to use concrete in cold weather, the difficulties are greatly multiplied. If concrete is allowed to freeze the setting is arrested, and the strength of the concrete greatly weakened by the destruction of the cement crystals. Another danger in frosty weather is that the grains of sand, the stones, the larger rocks on the bottom of the wall may be coated with ice, so that the cement will be given no chance to adhere to them.

Great care must be taken to see that everything used in the concrete is above the freezing point and will remain so for several hours after being mixed, so that the concrete will have a chance to set properly. The water can be made quite hot by running steam into it. The cement forms only a small proportion of the materials and need not be heated. The stone, gravel and sand are heated by piling them over long flues laid

on the ground at a slight inclination. The flues lead the heated gases from fires in the fire-boxes along under the piles of material to a low stack at the upper end. The larger rocks can be conveniently heated by immersing them in hot water, or by keeping them for some time in a large enclosed box with steam turned into it. A good way to warm, and at the same time to clean the concrete at the bottom of the form is to use a steam jet under a low pressure. This will warm the concrete and the forms and thaw any ice which may have been on them and can also be used to blow the dust, saw-dust and chips into little piles where they can be removed. Hot water is not very good for washing the forms in really cold weather, as it will soon cool and freeze, making things much worse than before; the walls should be left as dry as possible until just before the concrete is ready to be put in.

Considerable care is necessary in taking the concrete from the mixer to the forms. If conveyed in steel wheel-barrows or boxes, they should be rinsed out with hot water before being loaded. On one job it was necessary to hoist the concrete with a derrick and then dump it out and shovel it into wheel-barrows. In this case the concrete was dumped into a flat iron box with a fire under it and so kept warm until the wheel-barrows were ready to take it to the forms.

As soon as the concrete has been placed in the form and properly tamped, it should be covered over in some way to keep in the heat. One good method is to have long canvas sacks prepared of a proper size to fit in the walls and fill them with straw. These, when placed over the warm concrete, will keep in the heat for some time.

In one case, on a thin wall on an exposed part of the work, a line of old steam pipe was laid right in the form and left there. The concrete was placed around it and steam was kept running through the pipe for several hours until all danger of freezing was past.